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NAB LITTLE CREEK  
5090.3a

DRAFT SUPPLEMENTAL INVESTIGATION REPORT FOR SITE 12 AND 13 NAB LITTLE  
CREEK VA  
1/22/1996  
FOSTER WHEELER ENVIRONMENTAL SERVICES, INC.

**DRAFT  
REPORT**

*for*  
**SUPPLEMENTAL REMEDIAL INVESTIGATION**

**SITE 12 - EXCHANGE LAUNDRY WASTE  
DISPOSAL AREA  
SITE 13 - PUBLIC WORKS PCP DIP-TANK AND  
WASH RACK**

*at*  
**NAVAL AMPHIBIOUS BASE, LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA  
CONTRACT TASK ORDER 0247**

*Prepared For:*  
**NAVAL FACILITIES  
ENGINEERING COMMAND  
ATLANTIC DIVISION**  
*Norfolk, Virginia*

*Under:*  
**Contract N62470-89-D-4814**

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**January 22, 1996**

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## 1.0 INTRODUCTION

*KG* This Report was prepared to present the results of the field investigation as part of the Supplemental Remedial Investigation (SRI) phase of the Supplemental Remedial Investigation/Feasibility Study (SRI/FS) at the Naval Amphibious Base Little Creek (NAB Little Creek), in Virginia Beach, Virginia as part of the Installation Restoration (IR) program. **Figure 1-1** provides the location of NAB Little Creek. The two sites addressed during this SRI/FS include: Site 12, the Exchange Laundry Waste Disposal Area; and Site 13, the Public Works PCP Dip Tank and Wash Rack. **Figure 1-2** indicates the location of each site. The following sections describe the purpose and objectives for the SRI/FS.

### 1.1 Purpose

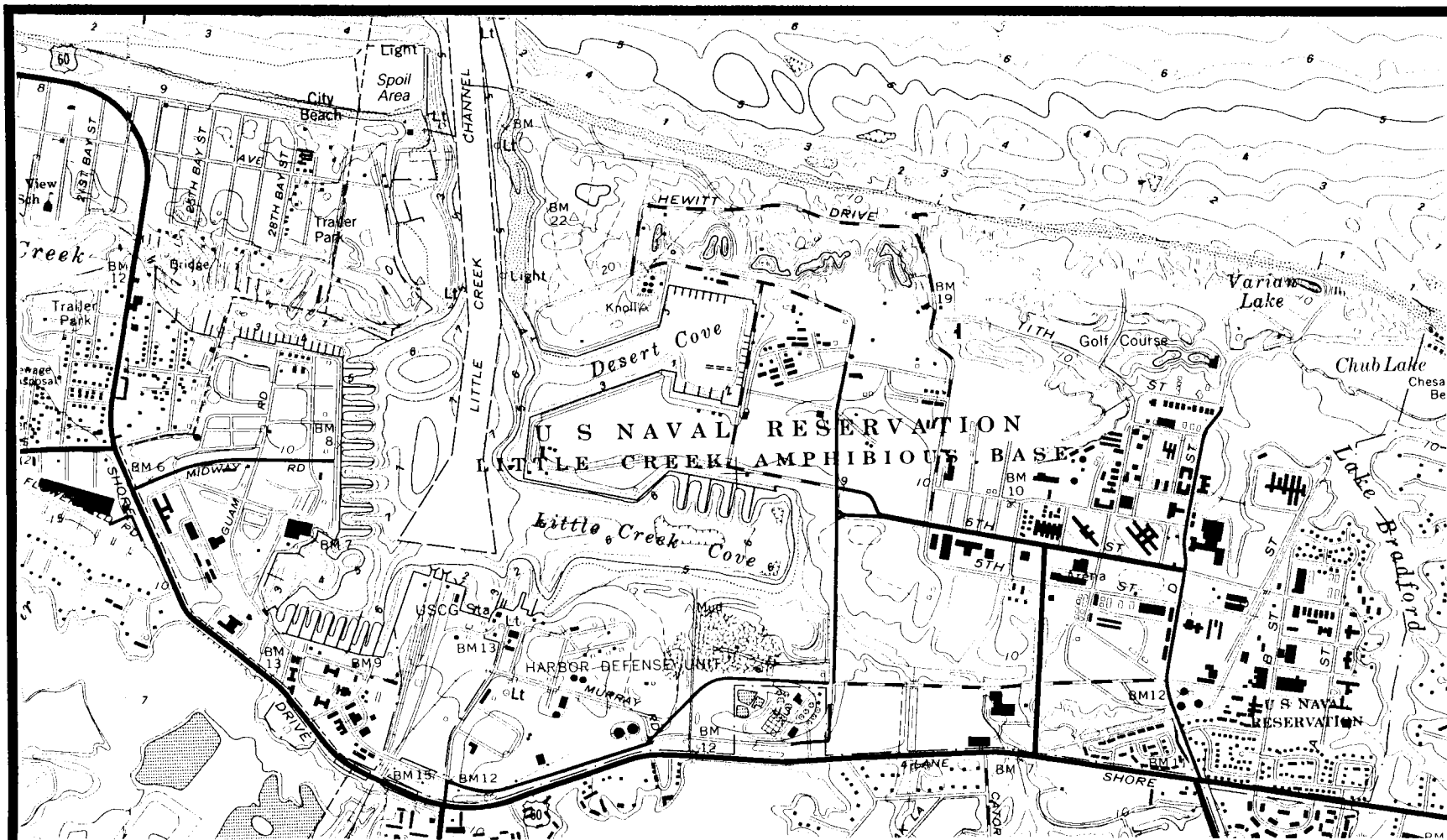
The SRI/FS was designed to obtain confirmation of site subsurface conditions and groundwater quality, and assess their impact on surface water quality for final determination of the necessary remedial actions at these sites.

### 1.2 Objectives

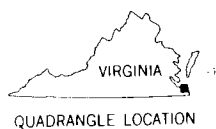
The SRI/FS collected site-specific data to satisfy the objectives presented in the Scope of Work and the Implementation Plan/Fee Proposal (IP/FP) dated June 24, 1994 for the SRI/FS at the NAB Little Creek, Virginia Beach, Virginia. Foster Wheeler Environmental Services (FWES) initiated the SRI/FS for NAB Little Creek in February, 1995 as per the issuance of the Final Site Management Plan (SMP). The work is being performed in accordance with the Final Work Plan (WP) and Final Field Sampling Plan (FSP) dated August 11, 1995, under Contract N62470-89-D-4814, Contract Task Order (CTO) 0247. *KG*

At Site 12, the specific SRI/FS objectives were:

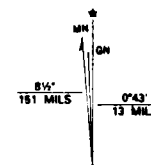
- Identify/determine if the subsurface soil is acting as the source of the VOC contamination as detected in previous investigations, by sampling and analyzing subsurface soil samples. *KG*
- Determine aquifer characteristics, such as hydraulic conductivity, through pumping and slug tests to define the mobility of contaminants and to aid in remediation design.
- Further characterize the sediments in the drainage canal adjacent to Site 12.
- Formulate a baseline risk assessment of possible threats to human health and/or the environment.



**LITTLE CREEK AMPHIBIOUS BASE  
VIRGINIA BEACH, VIRGINIA  
SITE LOCATION MAP**



Little Creek, VA Quadrangle  
7.5 Minute Series (Topographic)



UTM GRID AND 1986 MAGNETIC NORTH  
DECLINATION AT CENTER OF SHEET

Prepared by:  
Foster Wheeler Environmental Services

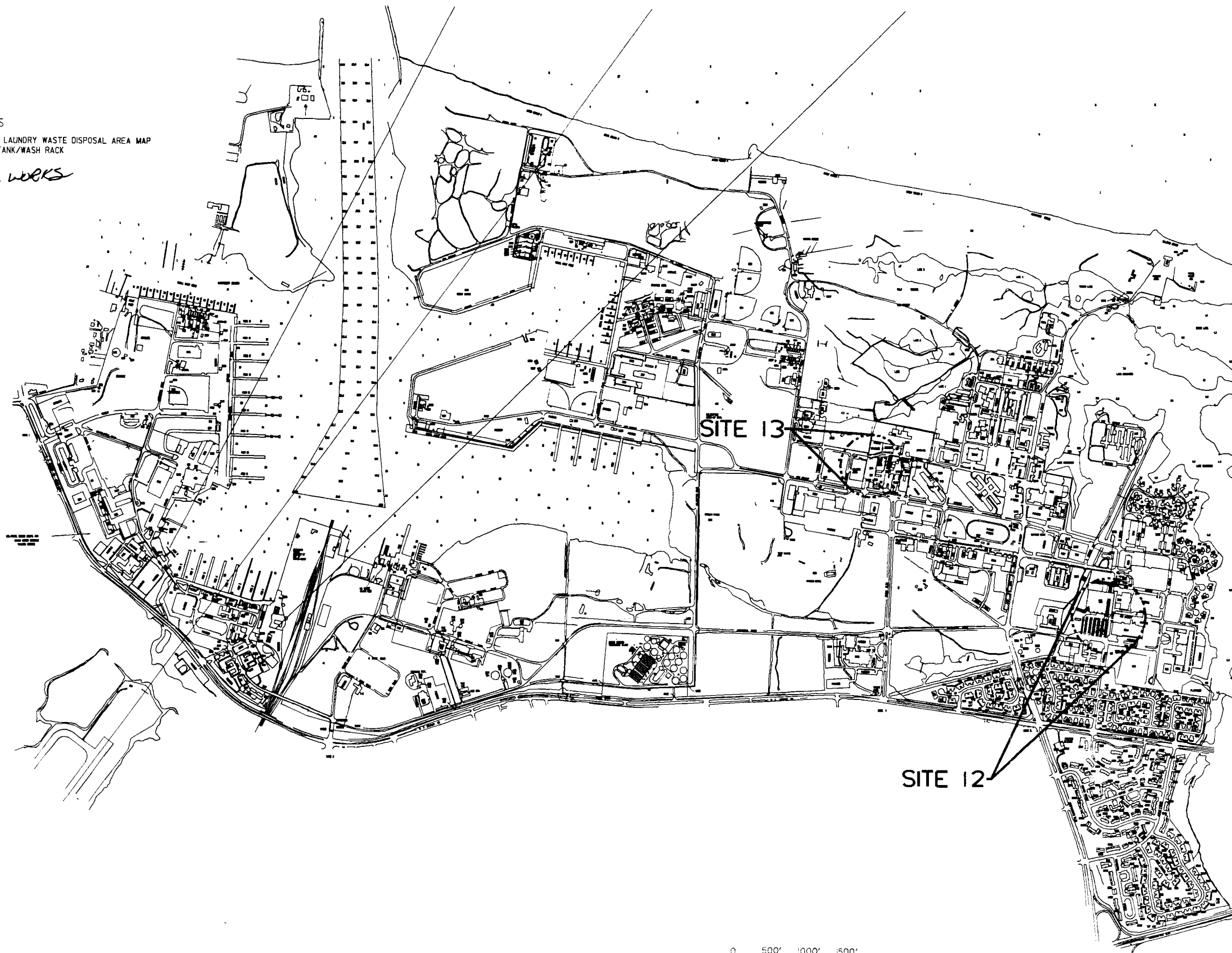
Figure 1-1  
Scale: 1" = 2000'



RI/FS SITES

- 12 EXCHANGE LAUNDRY WASTE DISPOSAL AREA MAP
- 13 PCP DIP TANK/WASH RACK

*PUBLIC WORKS*



SOURCE: BASE MAP PROVIDED BY LANTDIV

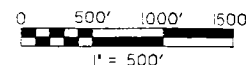


FIGURE 1-2  
BASE LOCATION MAP WITH  
SITE LOCATIONS  
NAB - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA

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At Site 13, the specific SRI/FS objectives were:

- Identify/determine if the subsurface soil is acting as the source of the PCP and vinyl chloride plumes, as detected in previous investigations, by sampling and analyzing subsurface soil samples. KG
- Determine the extent of a range of constituents which may impact human health and/or the environment by sampling and analyzing subsurface soil and shallow groundwater.
- Formulate a baseline risk assessment of any possible threat to human health and/or the environment by sampling and analyzing appropriate site media.

This Report presents the results of the scope of work for the SRI/FS, and has been prepared in accordance with U.S. Environmental Protection Agency (USEPA) guidance documents. The following documents were used to prepare the SRI/FS Report:

- Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (USEPA, October 1988)
- Superfund Public Health Evaluation Manual (USEPA, 1986)
- Superfund Exposure Assessment Manual (USEPA, 1986)

Several previous investigations were conducted at NAB Little Creek, and the reports for these investigations have been incorporated into this SRI/FS. These reports include:

- Initial Assessment Study (IAS) - Rogers, Golden, and Halpern, December 1984.
- Round 1 Verification Step (RVS) - CH2M Hill, October 1986.
- Phase II Environmental Study - ATEC Environmental Consultants, August 1990.
- Phase II Environmental Study - ATEC Environmental Consultants, April 1991.
- Draft Final Interim Remedial Investigation (Draft Final Interim RI) - Ebasco Environmental, November 1991.
- Pipeline Sampling Program - ATEC Environmental Consultants, December 1991.
- Background Ground Water Quality Study (Draft) - Applied Environmental, Inc., January 1992.
- Site Characterization Report for the Commissary Construction Project - Baker Environmental, Inc., June 1992

- Remedial Investigation/Feasibility Study (Final) (CTO-0042) - Foster Wheeler Environmental Services, November 1994.

### **1.3 SRI Report Organization**

This Report presents the results of the field activities and risk assessment tasks conducted at NAB Little Creek for the SRI/FS. Section 2.0 presents the background information for each site, and Section 3.0 presents the field investigation activities conducted at each site. Section 4.0 provides a discussion of the analytical and physical data gathered from each site. Section 5.0 presents analytical data, and the nature and extent of the contaminants at each site. Section 6.0 presents the baseline risk assessment, and Section 7.0 presents the conclusions and recommendations for NAB Little Creek.

*SITES 12 + 13*



## 2.0 SITE BACKGROUND AND PHYSICAL SETTING

NAB Little Creek, located in Virginia Beach, Virginia, provides logistic facilities and support services for local commands, organizations, homeported ships, etc., to meet the amphibious warfare training requirements of the Armed Forces of the United States. The facility is adjacent to the city line of Norfolk. The area surrounding this 2,147-acre facility is low lying and relatively flat with several fresh water lakes. *K6* Chubb Lake, Lake Bradford, Little Creek Reservoir/Lake Smith, and Lake Whitehurst are located on, or adjacent to, the facility.

NAB Little Creek was commissioned on July 30, 1945 by combining four contiguous activities. The Navy began purchasing land in the area from private estates and the Pennsylvania Railroad just prior to the outbreak of World War II. The first activity to be commissioned was the Amphibious Training Base in the southwestern corner of the present base near Little Creek Harbor. The base's mission was the training of landing craft personnel for operational assignments. Over the last fifty years, NAB Little Creek has expanded in both area and the complexity of its mission.

Environmental investigations at the base were initially documented in the IAS. In 1975, the Department of Defense initiated a program to investigate past disposal sites at military installations. This program, the Navy Assessment and Control of Installation Pollutants (NACIP), called for a three-phase operation. Phase One was the IAS to identify potentially contaminated areas. Phase Two was the Confirmation Study to verify and/or characterize the contamination. Phase Three included the Remedial Action. The program was changed in 1986 to reflect the requirements of the Superfund Amendment and Reauthorization Act (SARA) and is now called the Installation Restoration Program (IRP). This SRI/FS is being conducted as part of the IRP.

### 2.1 General Site Characteristics, Location and History

The following sections focus on the overall facility and are common to both Sites 12 and 13 at NAB Little Creek.

#### 2.1.1 Location

NAB Little Creek is located in the Atlantic Coastal Plain physiographic province in southeastern Virginia. This portion of Virginia is also referred to as the Hampton Roads Area. **Figure 1-1** shows the base location. The facility is bounded on the north by Chesapeake Bay, the east by Lake Bradford, and the south by Shore Drive. The facility's western boundary stretches over the Norfolk-Virginia Beach border. The central portion of the base is composed of Little Creek Cove, Desert Cove, and the Little Creek channel that connects with Chesapeake Bay. All of the installation lies within the jurisdictional boundary of Virginia Beach. Land use at the base is primarily industrial, while land development surrounding the site is suburban and industrial. The industrial development supports many large shipyards in the area.

NAB Little Creek has low subdued relief. Elevations at NAB Little Creek range from mean sea level along the Chesapeake Bay and Little Creek Cove to elevations as high as 40 feet above mean sea level at some of the larger dunes along the Bay. The average elevation of the facility is 10 feet above mean

sea level. The primary surface features of the Hampton Roads Area are many rivers, lakes, and marshy areas.

### **2.1.2 Climate**

The climate of the Hampton Roads Area is affected by the proximity of the Chesapeake Bay and Atlantic Ocean. These two large water bodies attenuate seasonal climatic changes resulting in mild winters and warm summers. Average total annual precipitation is 45 inches, with approximately 56 percent of the rainfall occurring from April to September. The maximum 24-hour rainfall reported at Norfolk is 11.4 inches in August 1964. Snowfall in the area averages approximately 7.2 inches per year. Temperatures for the region range from a winter average of 42°F to a summer average of 77°F. The hottest temperature recorded is 104°F in August 1980 and the lowest temperature on record for the area is -3°F in January 1985.

Relative humidity in the area ranges from an average of 57 percent at mid-afternoon to an average high of 78 percent at dawn. The prevailing wind direction is to the southwest with an average speed of 10.6 mph.

### **2.1.3 Population Distribution**

At full complement, NAB Little Creek currently has approximately 13,650 personnel. The base population increases during the summer, when much of the amphibious training of Navy and Marine Corps Reservists occurs. Approximately twenty-four ships are homeported at the base.

### **2.1.4 Site Descriptions**

The locations of the two sites being studied are shown on **Figure 1-2**, Base Map with Site Locations. A discussion of past activities and a physical description of each site are provided in the following paragraphs. **Table 2-1** summarizes the disposal and spill history at Sites 12 and 13 which are being further studied as part of this SRI/FS.

Information concerning each site was obtained from the reports of the earlier studies conducted, as listed in Section 1.0.

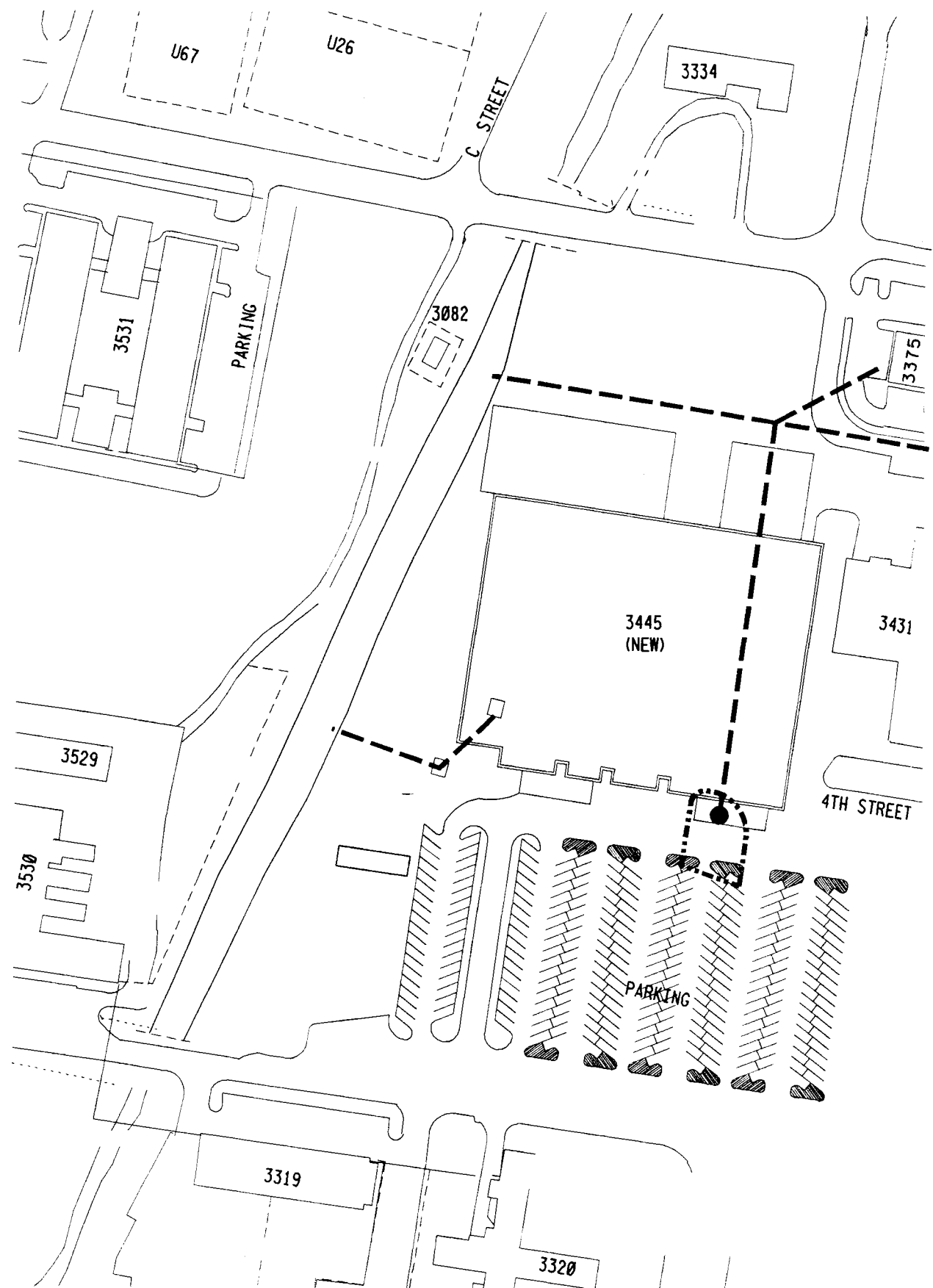
#### **2.1.4.1 Site 12 - Exchange Laundry Waste Disposal Area**

The former Exchange Laundry/Dry Cleaning Facility was located in the area of the present Building 3445, as shown on **Figure 2-1**, near the intersection of 3rd and B Streets, in the eastern portion of NAB Little Creek installation. Building 3323 was torn down in 1987. A catch basin and a portion of a storm sewer line were also removed at that time. The sewer line received dry cleaning wastes from the former Naval Exchange (NEX) laundry and drained to a canal that flows between Lake Bradford and Little Creek Cove. The remains of the storm sewer were removed and the area regraded for the construction of the existing commissary. The site now consists of any areas in the vicinity of the former storm sewer line where contamination still remains.

**TABLE 2-1**

**SUMMARY OF DISPOSAL AND SPILL SITES  
SITES 12 AND 13  
NAB LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

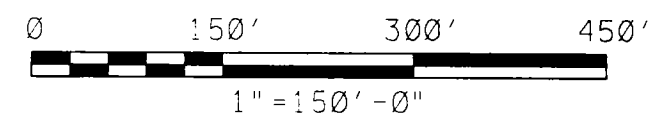
<b>Site Number</b>	<b>Name</b>	<b>Period of Operation</b>	<b>Types of Materials Disposal</b>	<b>Comments</b>
12	Exchange Laundry Waste Disposal Area	1973 to 1978	Perchloroethylene (PCE) sludge, soap, sizing, dyes	Disposal of 1,320 gallons of soap, sizing, sludges into storm drains
13	Public Works PCP Dip Tank and Wash Rack	Early 1960's to 1974	Pentachlorophenol (PCP), JP5, paint thinner, solvents, degreasers	PCP dripped from lumber onto ground, 150 to 200 gallons of kerosene, tar, paint, and solvents near wash rack




## LEGEND

- FORMER WATER AND STORM SEWER LINE  
..... SITE BOUNDARY

## GRAPHIC SCALE



REV.	DATE	DESCRIPTION	APPR.
REVISIONS			
FIGURE 2-1			
SITE MAP			
SITE 12			
NAB - LITTLE CREEK			
VIRGINIA BEACH, VIRGINIA			
<div> This Drawing is the property of the <b>FOSTER WHEELER ENVIRONMENTAL SERVICES</b> LIVINGSTON, NEW JERSEY AND IS LENT WITHOUT CONSIDERATION OTHER THAN THE BORROWER'S AGREEMENT THAT IT SHALL NOT BE RE- PRODUCED, COPIED, LENT, OR DISPOSED OF DIRECTLY OR INDIRECTLY NOR USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT IS SPECIFICALLY FURNISHED.</div>			
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As reported in the IAS, wastes were dumped into the storm sewer and thought to flow into the drainage canal via an outfall located immediately west of the former laundry building. However, review of the storm sewer configuration, conducted by Little Creek personnel in the summer of 1991, revealed that drainage from the catch basin reportedly used for the dumping actually flows north along B Street and then west along the north side of Building 3329, before flowing into the canal. Based on this information, the outfall for wastes dumped into the catch basin was approximately 350 feet north of the outfall sampled during the IRI investigation and the 1986 investigation. Drainage into the outfall pipe sampled during the IRI comes from a relatively small area of the parking lot around Building 3432.

Based on recommendations made by the Site Characterization report, dated June 1992, for the Commissary Construction Project, the storm sewer was removed and the area regraded.

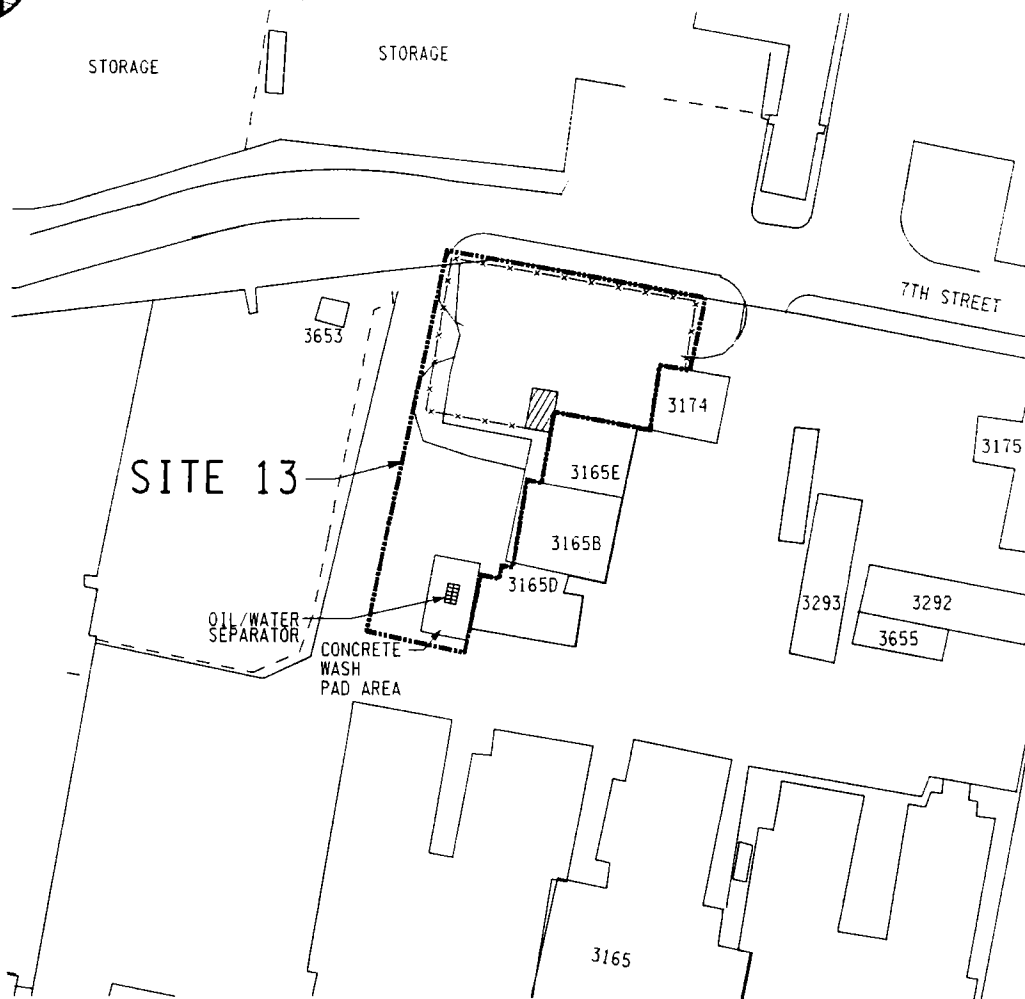
The ground surface at the site was mostly an asphalt-paved parking area associated with the car wash and former Buildings 3432, 3433, 3434, and 3435. A commissary building was commissioned at the site in early 1993. The former Building 3323 lot is level and grass-covered. The outfall immediately west of the car wash consists of a 12-inch galvanized iron pipe located approximately 3 feet below grade. This outfall is referred to as the "southern" outfall or discharge pipe. The outfall located north of Building 3434, the "northern" outfall which is connected to the catch basin used for disposal, was not inspected during the IRI field program, but probably has a configuration similar to the southern outfall. The catch basin used for disposal, located southwest of the intersection of 4th and B Streets, has since been removed.

The drainage canal is approximately 20 feet wide and 9 feet deep from grade. The sides of the canal are steep and covered with a relatively thick growth of vegetation. At the time of the April 1991 IRI site visit, the canal contained approximately 2 to 3 feet of water, i.e., the water level was 5 to 6 feet below grade. The canal is bordered by a 50-foot wide strip of vegetation on either side containing abundant trees, bushes, and weeds. Water within the canal was brownish in color and appeared to be stagnant during the IRI. During a field visit by FWES personnel during January 1992, the water in the canal was flowing in a southwest direction. Miscellaneous trash and refuse were observed in many places along the banks of the canal and the wooded areas.



The IAS reported that wastes dumped into the storm sewer and canal included tetrachloroethane (PCE) sludges, soap, sizing, and dyes. The period of operation and disposal lasted from 1973 until 1978, during which an estimated 1,320 gallons of waste were dumped into the storm sewer drain. Of this total, approximately 200 gallons were PCE sludges. In addition to the dumping, smaller quantities of PCE and other wastes may have entered the storm sewer through run-off from spills or overflow of waste containers.

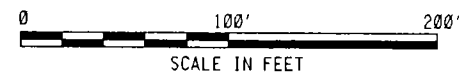
#### 2.1.4.2 Site 13 - Public Works PCP Dip Tank and Wash Rack

The location of the former PCP Dip Tank and Wash Rack, shown on Figure 2-2, was near the intersection of 7th and F Streets, in the eastern portion of NAB Little Creek installation. The site consisted of the dip tank formerly used to treat wood with pentachlorophenol (PCP), an adjacent area that contained drying racks for the PCP-treated wood, an open area formerly used by the Public Works Department for storage of supplies and equipment, and a concrete wash rack at the southwestern end of



### LEGEND

-  LOCATION OF FORMER PCP DIP TANK
-  FENCING INDICATES APPROX. DRYING AREA BOUNDARY.



**FIGURE 2-2**  
**SITE MAP**  
**SITE 13**  
**PUBLIC WORKS PCP DIP TANK AND**  
**WASH RACK AREA MAP**  
**NAB - LITTLE CREEK**  
**VIRGINIA BEACH, VIRGINIA**

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PROJECT: 01-23-92

DATE: 12/01/93

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that area. The site is bounded on the north by 7th Street, on the east by Buildings 3165D and 3165E, on the south by Building 3165, and on the west by a paved driveway and fenced storage area. The combined areas consist of approximately 30,000 square feet.

The PCP Dip Tank was located behind Building 3165E and used from the early 1960s until 1974. The dimensions and construction materials are unknown, but it reportedly contained 300 to 400 gallons of PCP. Wood was dipped into the tank and set on racks for drying. These racks were located immediately north of the dip tank between the tank and 7th Street. The area formerly containing the PCP dip tank and drying racks has since been paved with asphalt, fenced, and converted to a Public Works Department storage area. The dip tank was cleaned out approximately every 6 months, at which time the approximately 55 gallons of PCP sludge generated are believed to have been disposed in the Amphibious Base Landfill (IAS, 1984). All remaining PCP solution and associated sludges were removed from the tank in 1975. The tank itself was dismantled and disposed in 1982.

The wash rack and associated storage area, both of which were immediately south of the dip tank and west of Building 3165D, continue to be used by the Public Works Department. The wash rack, located at the southwestern corner of the storage area, is a concrete pad with bermed sides and centrally-located deck drain. The rack is used by the Public Works Department to clean vehicles, equipment, and miscellaneous objects with steam and chemical cleaners. Wash water and other run-off from the rack drains through the central deck drain into an oil/water separator located under the paved driveway between the wash rack and Building 3165. The oil/water separator is accessible via a rectangular steel manhole located in the driveway. The contents of the separator, as observed in April 1991, included both oily sludge and oil.

The unpaved storage area immediately north of the wash rack, between the wash rack and the former location of the PCP dip tank, was used for the storage of various materials and equipment. The IAS reported evidence of readily observable solvents, paint, fuel, and tar staining the surface in this area. At the time of the April 1991 site investigation during the IRI, the graveled area was free of surface staining, indicating that although the area continues to be used as a storage yard by Public Works, the occurrence of spillage and other releases has been significantly reduced.

## **2.2 Regional Geology**

NAB Little Creek area is located within the Atlantic Coastal Plain Physiographic Province. The region is underlain by several thousand feet of unconsolidated deposits of gravel, sand, and clay ranging in age from Lower Cretaceous to Holocene. These sediments overlie a bedrock basement of Precambrian and Triassic/Jurassic age. Generally, the unconsolidated deposits dip and thicken gently eastward, with thicknesses ranging from 2,000 to 4,000 feet. The Coastal Plain of Virginia is divided into six units. From oldest to youngest, they are:

- Patuxent Formation (Transitional Beds),
- Mattaponi Formation,
- Nanjemoy Formation,
- Calvert Formation,

- Yorktown Formation, and
- Columbia Group (Teifke, 1973).

The Patuxent Formation of Early Cretaceous age overlies the bedrock "basement." The Patuxent is an alternating sequence of fine gravel, coarse sand, and silty sandy clay. Sand within the Patuxent is mainly tan, gray, or white and characteristically feldspathic.

In southeastern Virginia, transitional beds of Early Cretaceous age are found above the Patuxent Formation. The transitional beds consist of sand, silt, and clay. These beds are either intermediate in composition and texture or comprise alternations of lithotypes characteristic of the Patuxent and Mattaponi Formations.

The Mattaponi Formation is of Upper Cretaceous, Paleocene, and Eocene age. The formation is of marine origin and characterized by beds of quartz-glaucinite sand, glauconitic clay, and shells (Teifke, 1973).

The Calvert Formation of Miocene age, which is commonly consolidated, consists largely of clay and silty clay. A basal sand member consisting of medium-to-coarse sand may be present in the Calvert Formation, with some beds or lenses of phosphatic clay.

The Yorktown Formation consists of more abundant and markedly coarser sand and gravel beds, and more abundant and thicker shell beds, than the underlying Calvert Formation. The Yorktown is also lighter in color than the upper member of the Calvert.

The uppermost geologic unit, the Columbia Group, is characterized by beds of light-colored clay, sand, and silt. The average thickness of the unit ranges from 20 feet in the western part to 50 feet in the eastern part of the physiographic province (Oaks and Coch, 1973).

The natural surficial geologic units at NAB Little Creek are an unnamed Holocene sand, which forms the coastal barrier islands and beach-dune ridges bordering Chesapeake Bay, and the Lynnhaven Member of the Upper Pleistocene Age Tabb Formation (Mixon et al., 1989).

Sites 12 and 13 are located in the Lynnhaven Member of the Upper Pleistocene Age Tabb Formation. This unit consists of clayey and silty sand and sandy silt grading downward into a pebbly and cobbly fine to coarse gray sand. The thickness of the Lynnhaven Member of the Tabb Formation ranges from 0 to 20 feet (Mixon et al., 1989). This unit contains the Columbia, or water table aquifer, at the project site.

### **2.3 Soil Sequences**

The natural soils at NAB Little Creek have been largely disturbed by construction activities. The IAS estimated that 90 percent of the surface sediments at the base are either urban or dredged from the surrounding waterways, and other soils have been imported. Only 14 acres of undisturbed marsh land remain out of the total 2,147 acres present at NAB Little Creek.



The US Department of Agriculture, Soil Conservation Service (SCS, 1985) lists two general soils for the NAB Little Creek: KE

- Newhan-Duckston-Corolla - occurring in the coastal region along Chesapeake Bay, characterized as excessively to poorly drained and formed in marine or eolian sediments.
- Udorthents-Urban Lands - occurring throughout the rest of the site, characterized as well to moderately drained with a loamy substratum, and formed primarily in disturbed sediments.

## **2.4 Regional Hydrogeology**

The hydrogeology of the Virginia Coastal Plain has been characterized by many authors. The uppermost water table aquifer, known as the Columbia Aquifer, is the primary unit of concern at the NAB Little Creek installation. The Columbia Aquifer extends from the ground surface to a depth of 20 feet below mean sea level in the Little Creek area and is underlain by the upper unit of the Yorktown Formation. KE

The hydrogeologic framework of the Norfolk area includes four principal aquifers, one unconfined and three confined. These aquifers, and their geologic unit equivalents, are:

- The unconfined water table aquifer, mostly in the Columbia Group,
- The Yorktown Aquifer, in the upper part of the Yorktown Formation,
- The Eocene-Upper Cretaceous aquifer, in the lower part of the Calvert and Mattaponi Formations, and
- The lower Cretaceous aquifer, in the Potomac Group.

Confining beds, or aquitards, between and within the aquifers retard, but do not prevent, vertical movement of groundwater. Overall, the water-bearing units comprise a leaky-aquifer system with groundwater generally flowing easterly towards the Chesapeake Bay. The lower Cretaceous Aquifer exhibits the most confinement (Siudyla, et al., 1981).

The Columbia Aquifer lies in beds and lenses of sand and some gravel, shell beds, silt, sandy clay, and clay. The major water-bearing strata, consisting of sand and shell beds and lenses, are highly heterogeneous and discontinuous due to the marine estuarine environments in which they were deposited. The sand units yield quantities adequate for domestic and small industrial demands for non-potable water. The Columbia Aquifer is not used as a potable source of water in the Virginia Beach-Norfolk area. Individual well yields range from 5 to 50 gallons per minute (gpm), and specific capacities range from about 1 to 2 gallons per minute per foot (gpm/ft) (Siudyla, et al., 1981). Groundwater in coastal regions has been found to be saline (Hamilton and Larson, 1988).

Recharge for the Columbia Aquifer comes primarily through infiltration of precipitation. The IAS estimated that approximately 50 percent of the precipitation which falls in the area infiltrates, and 78 percent of the water which infiltrates reaches the water table. Regional hydraulic gradients within the water table aquifer are quite low because of the lack of topographic relief.

The Yorktown Aquifer underlies the Columbia Aquifer. Major water-bearing zones comprising the Yorktown Aquifer are found in the upper 50 to 100 feet of the Yorktown Formation. These water-bearing zones are made of beds of fine to coarse sand, gravel, and shells approximately 5 to 20 feet thick. The Yorktown Aquifer generally is separated from the overlying water table aquifer by beds of silt, clay, and sandy clay about 20 to 40 feet thick (Siudyla, et al., 1981). Groundwater in coastal regions may be saline in the lower part of the aquifer (Hamilton and Larson, 1988).

Well yield and specific capacity data for the Yorktown Aquifer are limited. Reported well yields range from 12 to 304 gpm with an average of 87 gpm. Specific capacities range from 0.5 to 14.4 gpm/ft with an average of 5 gpm/ft. Area domestic well drillers indicate that smaller diameter, 1-1/4 inch to 2 inch, well yields range from 5 to 50 gpm (Siudyla, et al., 1981).

The Eocene-Upper Cretaceous Aquifer is found at a minimum depth of 500 feet in the western section of the Norfolk area to depths of approximately 1,000 feet in the eastern section. The aquifer generally lies in one or two fine- to medium-grained glauconitic sand beds, 10 to 30 feet thick, interbedded with silt and clay (Siudyla, et al., 1981).

The Lower Cretaceous Aquifer lies in interbedded gravel, sand, silt, and clay. In most cases, it is separated from the Eocene-Upper Cretaceous Aquifer by clay and silt units 50 feet or more thick. Beds of clay divide the aquifer into several prolific zones. The top of the aquifer ranges from 600 feet below land surface in the northwestern study area to about 1,100 feet in the eastern section. The bottom of the aquifer rests on basement bedrock at a depth of 2,000 feet in the west to about 4,000 feet in the east. Well yields for this aquifer range from 200 to 1,000 gpm and specific capacities range from 2.9 to 30.8 gpm/ft (Siudyla, et al., 1981).

#### **2.4.1 Surface Water**

NAB Little Creek is located adjacent to Chesapeake Bay, as shown on **Figure 1-1**. Based on topographic mapping of the site, most surface drainage flows into the Little Creek Tidal Inlet, which consists of Little Creek, Desert Cove, Little Creek Channel, and Little Creek Cove, and then into Chesapeake Bay through the inlet. On the eastern part of the base, surface drainage flows via unlined canals into five lakes, of which Lake Bradford and Chub Lake are the largest. These lakes do not have surface outlets into Chesapeake Bay.

Chub Lake and Lake Bradford are interconnected freshwater lakes, not directly connected with other surface water bodies. The water level in these two lakes is regulated by the release of overflow into a canal which drains to the southwest and eventually into Little Creek Cove. Chub Lake and Lake Bradford may receive significant amounts of salt water from the Chesapeake Bay during extreme storm events (IAS, 1984).

As described in the IAS, NAB Little Creek is influenced by tidal fluctuations. Little Creek and Little Creek Cove experience a semidiurnal tide of approximately 2.5 feet, but because of the limited areal extent of the harbor, tidal currents are limited. As a result of previous studies, the effects of the tidal fluctuations on the groundwater flow and contaminant migration at the Base vary by location. Tidal effects on the groundwater flow direction at Sites 12 and 13 are discussed in Sections 4.1.4 and 4.2.4, respectively.

A narrow east-west trending canal, located south of NAB Little Creek, carries outflow from the freshwater Lake Whitehurst Reservoir and Little Creek Reservoir/Lake Smith to Little Creek Cove. The 4,000-foot long drainage canal originates from Little Creek Reservoir. Lake Smith is designated as an emergency source of potable water.

## **2.5 Summary and Review of Existing Data**

FWES's review of existing data concentrated primarily on assessing the chemical and hydrogeologic data generated during previous investigations. The focus was on site contaminants, site hydrogeology, and the migration of contamination in the soil, groundwater, and surface water/sediment medias.

### **2.5.1 History of Environmental Investigations**

#### **2.5.1.1 Initial Assessment Study**

The Initial Assessment Study (IAS) at NAB Little Creek was completed in December 1984 by Rogers, Golden, and Halpern, of Philadelphia, Pennsylvania. Its purpose was to identify and assess sites posing a potential threat to human health or the environment due to contamination resulting from prior hazardous waste management activities. The study entailed the collection and evaluation of archival and activity records relating to waste generation, handling and disposal, characterization of physical conditions at the site such as soil, hydrogeology, etc., and identification of migration pathways and potential receptors. The results of these data evaluation efforts were used to develop recommendations concerning the need for a Confirmation Study at a given site, the goal of which was to verify the presence of contamination and determine the need for further characterization and/or remediation.

The IAS examined 17 sites at NAB Little Creek. Six sites were recommended for Confirmation Studies, Sites 7, 9, 10, 11, 12, and 13. Of the remaining 11 sites, mitigation measures were recommended for four of the sites, Sites 4, 5, 15, and 16, and no further action was recommended for six of the sites, Sites 1, 2, 6, 8, 14, and 17. Site 3, the West Annex Fuel Spill, was addressed under a separate action to recover free-floating oil from the water table. Site 17, the Building 1256 Motor Oil Disposal Area, was added to the PSI by the Navy.

The IAS recommendations to conduct Confirmation Studies were based largely on the finding that contaminants from disposal areas may migrate toward surface water bodies with little attenuation, owing to a lack of clays and organic material, and in a relatively short time because of high hydraulic conductivities. The potentially affected surface water includes Little Creek Cove, Lake Bradford, and Lake Smith. Lake Bradford and Lake Smith are used for recreational purposes, and Lake Smith serves

as the back-up municipal water supply for the Norfolk-Virginia Beach area. Delineation of an actual threat or risk was not possible due to the lack of site-specific hydrogeologic and groundwater quality data.

The IAS presented a number of detailed recommendations concerning the installation and sampling of monitoring wells, the sampling of surface soil, surface water and sediment, and the types of laboratory analyses to be completed. The recommendations also addressed well completion depths and water level monitoring requirements. Many of the recommendations were aimed at resolving the data gaps identified in the IAS. These recommendations, with slight changes, became the Scope of Work for the RVS.

#### 2.5.1.2 Round 1 Verification Step

The Round 1 Verification Step (RVS) at NAB Little Creek, the first step in the Confirmation Study process, was completed in October 1986. The purpose of the study was to verify the presence and/or absence of contamination at the six sites recommended in the IAS for a Confirmation Study. The scope of the RVS activities at each site was established by the recommendations presented in the IAS, with notable deviations concerning the number of monitoring wells completed and samples collected.

As part of the work conducted for the RVS, 31 monitoring wells were installed to facilitate the collection of groundwater samples and hydraulic head data to determine groundwater flow directions. Surface water and sediment samples were collected to investigate impacts on nearby surface water bodies and determine whether contaminated run-off was migrating from three of the six sites. Subsurface soil samples also were collected to delineate the vertical extent of contamination in probable source areas.

As stated in the RVS, the results of the Round 1 sampling and analysis activities indicated that little or no contamination was leaving any of the landfill sites. Contamination was detected in one or more environmental media at the other three sites. These results indicated that contamination was being released from these three sites, but the magnitude and distribution of this contamination could not be determined on the basis of the Round 1 findings alone. The results of the sampling and analysis activities were used to develop recommendations for additional investigations at all six sites. These recommendations were generally limited to continued or expanded sampling conducted during the Interim RI to confirm the Round 1 activities (IRI, 1991).

#### 2.5.1.3 Interim Remedial Investigation

The IRI was conducted to determine whether or not further characterization activities or remedial action was warranted at Sites 7, 9, 10, 11, 12, and 13. The objectives of this investigation, as identified by Naval Facilities Engineering Command, were to conduct a second round of sampling at the six sites sampled for the RVS, and to integrate the historical and newly acquired data along with site-specific recommendations for further action, into a single document. The data were used to develop recommended response actions, a human health assessment, and site specific recommendations concerning additional characterization.

#### 2.5.1.4 Environment Assessment - Site 12

ATEC Environmental Consultants (ATEC) completed a two-phase environmental assessment of Site 12 in 1990 and 1991. The Phase 1 analysis, conducted from June 1990 through August 1990, entailed the drilling, installation, and sampling of eight monitoring wells, the collection of a soil sample from each monitoring well boring, and the collection of three sediment samples from along the drainage canal.

The second phase of the ATEC assessment was conducted from March 1991 through April 1991. The purpose of this work was to verify the Phase 1 findings and provide a more detailed delineation of the extent of groundwater contamination at Site 12. The specific activities completed for Phase 2 included the drilling, installation, and sampling of two additional monitoring wells, collection of a second round of samples from the eight existing wells, and the establishment of vertical well elevation data in order to determine the direction of groundwater flow.

#### 2.5.1.5 Background Groundwater Quality Study

A background groundwater quality study was conducted at NAB Little Creek in October 1991. The purpose of this study was to collect, organize, and present data on background water quality and groundwater conditions. The groundwater quality information was obtained from a network of monitoring wells installed for this study. Since the objective was to obtain representative samples from all portions of the base, the wells were located throughout the base, and areas of known or suspected contamination were avoided. Information on the hydraulic characteristics of the water table aquifer was obtained by conducting pump tests at three locations.

Eight monitoring wells were installed at NAB Little Creek. Soil samples were collected from each well boring and analyzed for TAL Metals and moisture content. The wells were sampled and analyzed for TCL organics, TAL inorganics, TPH, TOC, TOX, ethylene dibromide, cyanide, hexavalent chromium, and anions.

Water level measurements were taken in the background monitoring wells and plotted to determine groundwater flow patterns. The data was not collected at the same time, however, and groundwater may have been subject to tidal fluctuations. The general direction of groundwater flow for most of the eastern portion of the site was found to be to the north, towards Chesapeake Bay and Little Creek Harbor. In the western portion of the base, the groundwater appeared to generally flow to the west.

#### 2.5.1.6 Site Characterization - Site 12

A Site Characterization was conducted for the new commissary construction site at NAB Little Creek in January 1992. A subsurface investigation evaluated the lateral and vertical extent of potentially contaminated environmental media at the site. Soil borings were drilled in proximity to the location of former USTs, and each boring was converted into a monitoring well. Soil and groundwater samples from the borings and wells were analyzed to evaluate the extent of contamination. A geophysical investigation and soil gas survey also were conducted to identify potential contaminated areas of concern for subsequent sampling. The geophysical data indicated the presence of existing utilities and buried metal objects from

the demolition at the site. The Site Characterization recommended the installation of a passive soil gas reduction system with a liner to reduce the possibility of vapor migration into the proposed new building.

#### 2.5.1.7 RI/FS

In 1993, FWES conducted an RI/FS/RA of Sites 7, 9, 10, 12, and 13. The purpose of the RI/FS/RA was to fill information gaps and collect additional site-specific data necessary to fully evaluate site conditions, determine potential risks posed by each site, and develop and evaluate remedial action alternatives to mitigate any risks found. At this same time, FWES also conducted an SI at Sites 5 and 16. These investigation included soil, groundwater, sediment, surface water, and soil gas sampling. Additional groundwater monitoring wells were also installed.

The RI/FS recommended that additional information was required from both Sites 12 and 13. Specifically, for Site 12, the RI/FS recommended that additional hydrological characterization using slug tests, pump tests, and subsurface grain analysis be required for the evaluation of treatment or containment options. Additional groundwater sampling was also recommended. Sampling of subsurface soil, and surface water, was also recommended to investigate source locations.

The RI/FS recommended for Site 13 that additional investigations such as slug tests, pump test, and subsurface analysis could assist in determining the migration pathways of the PCP contamination. Additional groundwater monitoring was also recommended.

### 2.5.2 Site Specific Background

The following sections detail the specific field activities and findings of the previous studies performed at each site.

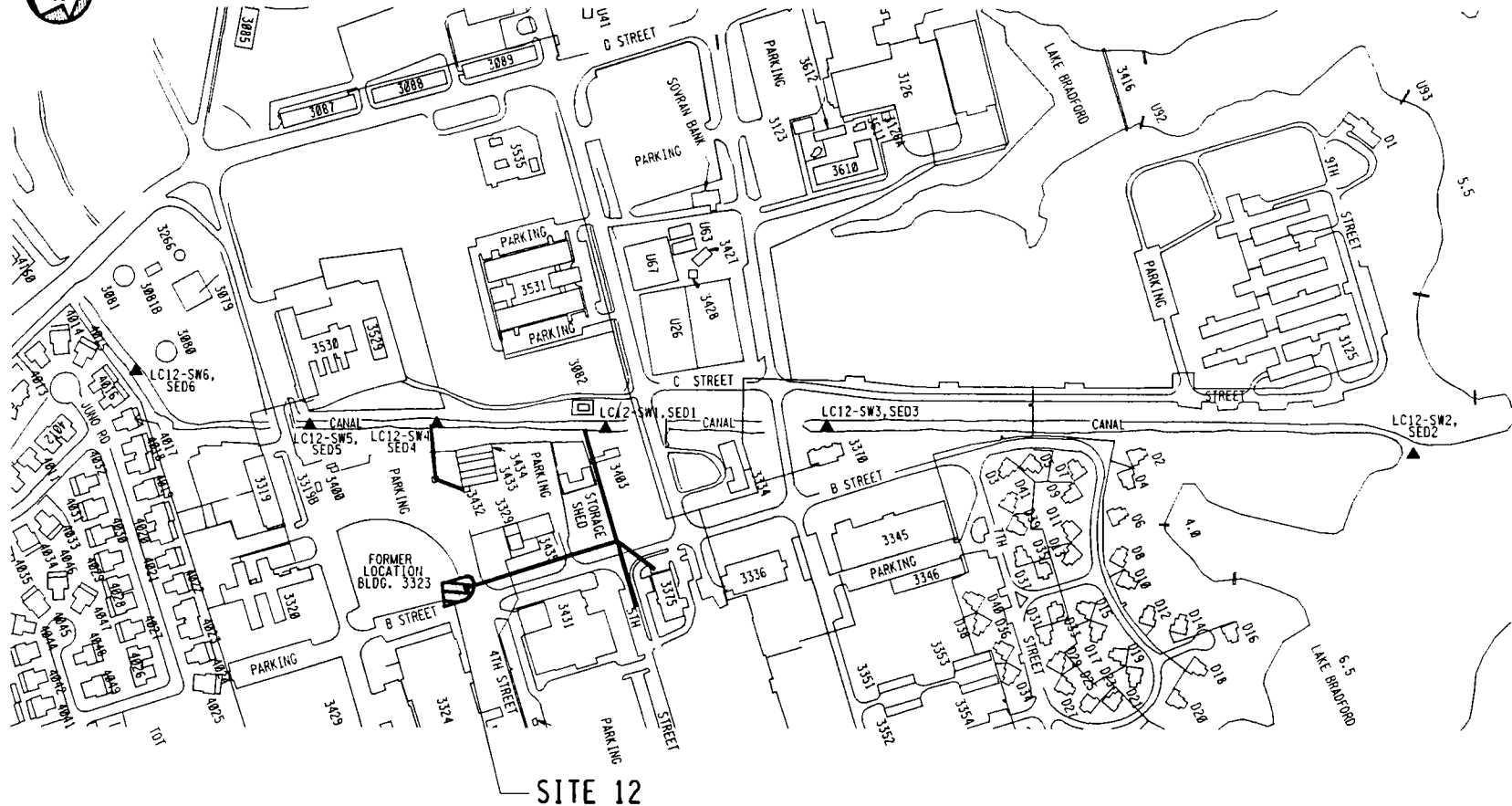
#### 2.5.2.1 Site 12 Exchange Laundry Waste Disposal Area

Initial Assessment Study Because of the time that had passed since the disposal practices ended, the IAS anticipated that the PCE-laden sediments may have been buried by more recent material. It was recommended that a total of six lake and canal sediment samples be collected. The sampling program should be designed to determine the proper depth interval for the sampling, along with the geographic location.

Round 1 Verification Step The RVS included the collection of six surface water and six sediment samples. The sample locations are illustrated on **Figure 2-3**. The results of sampling are provided in **Table 2-2**. The sediment samples were collected at depths of 0.0 to 0.5 feet.

Volatile organic compounds (VOCs) were detected in four of the surface water and all of the sediment samples. Total VOCs in the surface water ranged from not detected to 43.3 µg/l. Total VOCs in the sediment ranged from 11 µg/l to 598 µg/l.

The RVS concluded the primary potential pathway for contaminant migration from the site was likely to be surface water transport southwest toward Little Creek Cove from Lake Bradford. However, at the



SITE 12

**LEGEND**

- ▲ SEDIMENT & SURFACE WATER SAMPLING LOCATION
- DRAINAGE LINE

SOURCE: ROUND 1 VERIFICATION STEP, CH. M. HILL, 10/86



**FIGURE 2-3  
PREVIOUS SAMPLING LOCATIONS  
SITE 12  
ROUND 1 VERIFICATION STEP  
NAB - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**



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TABLE 2-2

SUMMARY OF ANALYTICAL RESULTS FOR SURFACE WATER AND SEDIMENT SAMPLES  
 SITE 12: EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAB LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 ROUND 1 VERIFICATION STEP  
 OCTOBER 1986

PARAMETER	LC12-SW1	LC12-SW2	LC12-SW3	LC12-SW4	LC12-SW5	LC12-SW6	LC12-SED1	LC12-SED2	LC12-SED3	LC12-SED4	LC12-SED5	LC12-SED6
<b>VOLATILE ORGANIC COMPOUNDS</b>												
TRICHLOROETHENE				7.3	4.1	3.1						
TETRACHLOROETHENE				17	6.7	5.3						
TRANS-1,2-DICHLOROETHENE					26	19						2.5
VINYL CHLORIDE												2.9
TOLUENE												9.1
METHYLENE CHLORIDE				19			280	22	11	7.9	37	5.5
ACETONE							230			18		
CHLOROFORM	2.1				1.6			4.6			2.4	2.7
TRICHLORO TRIFLUOROETHANE							71					
3-METHYL PENTANE							17					

**NOTES:**

All results in parts per billion (ppb)

Blank indicates compound was not detected



time of sampling, the direction of surface water flow was not easily discernible. The presence of VOC contaminants downstream of the site indicated a potential for contamination leaving the site to pose a threat to human health. However, because there may have been other sources of VOCs in the surface water, contamination could not be directly attributed to the site. The RVS recommended a second round of sampling including six surface water and two sediment samples. The RVS recommended the sediment samples be collected near the outlet of the drainage pipe.

Phase II Environmental Site Study A two-phase environmental study was performed by ATEC Environmental Consultants in the Exchange Laundry Waste Area. The initial phase was performed in June through August of 1990, and the follow-up was performed in March 1991. The location of the wells installed are indicated on **Figure 2-4**. Soil and groundwater samples were collected. The results of sampling are provided in **Tables 2-3** and **2-4**.

VOCs were detected in both soil samples. Methylene chloride and chloroform were detected in both samples, and 1,1,1-trichloroethane was detected in MW-9. Several VOCs were detected in the groundwater samples at levels ranging from not detected to 470  $\mu\text{g/l}$ .

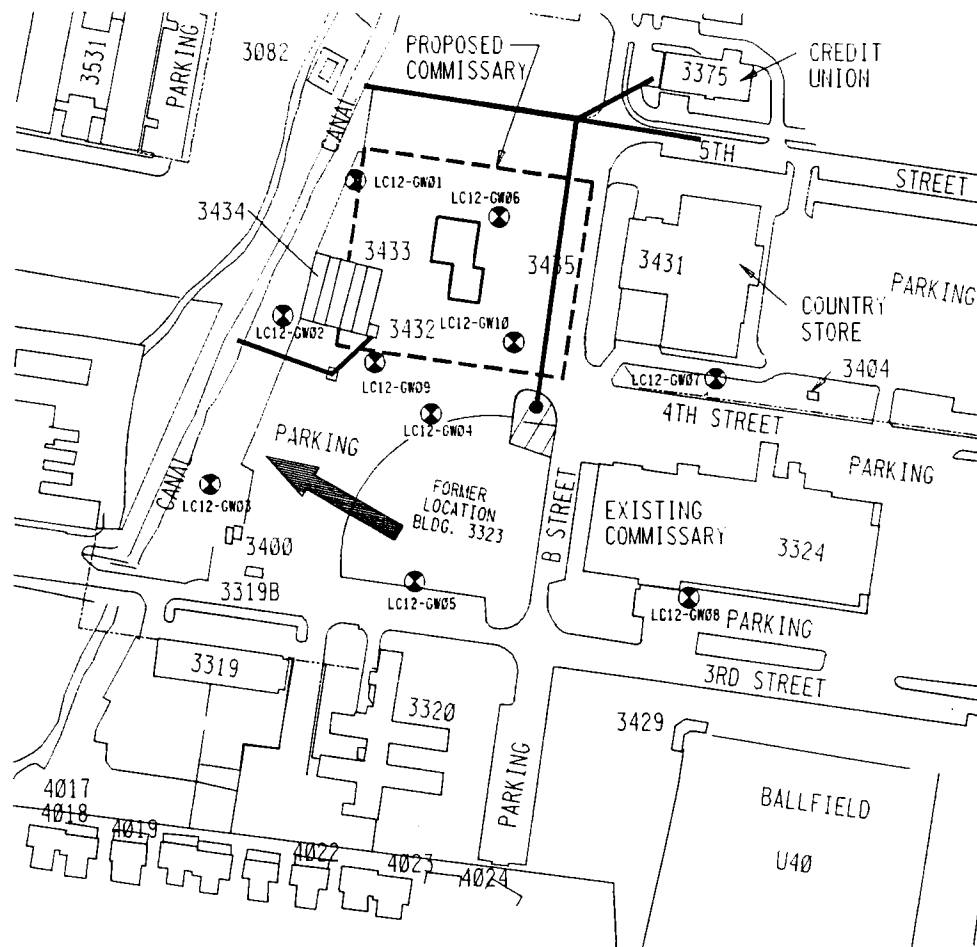
The extent of VOCs was not fully delineated. Based upon their study, ATEC stated groundwater appeared to be migrating from the site to the drainage ditch. ATEC recommended additional monitoring wells be installed and sampled for VOCs in order to delineate the extent and magnitude of the contamination plume.

Interim Remedial Investigation IRI field activities at the Exchange Laundry Waste Disposal Area consisted of the collection and analysis of surface water and sediment samples from the drainage canal linking Lake Bradford and Little Creek Cove. The sediment samples were both collected directly adjacent to the southern discharge pipe from depths of 0 to 6 inches and 6 to 12 inches. A total of seven surface water and three sediment samples were collected from the canal for analysis. The data generated by these activities were used to confirm the RVS findings concerning whether discharge of wastes from the former laundry facility had resulted in contamination of the canal.

Groundwater flow and contamination data were not generated as part of the IRI, but were the subject of a separate study completed by ATEC. The results of this study have also been incorporated into the IRI. Potentiometric data presented in the 1991 ATEC report indicated groundwater flow at Site 12 was westward, toward the drainage canal. Given the assumed depth of the canal, the drainage canal probably functions as a local hydrologic boundary, or discharge area, for the water table aquifer. If so, groundwater in the water table aquifer beneath the site would eventually discharge into the drainage canal.

Surface water and sediment samples were collected in December 1990 from the locations shown on **Figure 2-5**. **Table 2-5** presents the results of the sampling. No VOCs were detected in any of the surface water or sediment samples.

As a result of the sampling and analysis operations, the IRI concluded there had been a significant decline in the number of contaminants and magnitude of contamination in the drainage canal that formerly received discharges from the laundry waste disposal area. The apparent clean-up of the canal is most likely a result of both the discontinued discharge of waste from the storm sewer, as well as natural



**LEGEND**



MONITORING WELLS



GROUNDWATER FLOW DIRECTION

SOURCE: DRAFT INTERIM REMEDIAL INVESTIGATION REPORT, EBASCO, 5/91

0 100' 200' 300'  
SCALE IN FEET

**FIGURE 2-4  
PREVIOUS SAMPLING LOCATIONS  
SITE 12  
ATEC ENVIRONMENTAL SITE STUDY  
LITTLE CREEK AMPHIBIOUS BASE  
VIRGINIA BEACH, VIRGINIA**



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**TABLE 2-3**

**SUMMARY OF ANALYTICAL RESULTS FOR SOIL SAMPLES  
SITE 12: EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
NAB LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA  
PHASE II ENVIRONMENTAL SITE STUDY  
MARCH 1991**

<b>PARAMETER</b>	<b>MWS-9</b>	<b>MWS-10</b>
<b>PURGEABLE HALOCARBONS</b>		
METHYLENE CHLORIDE	3.2	16
CHLOROFORM	0.30	24
1,1,1-TRICHLOROETHANE	0.35	

**NOTES:**

All results in parts per billion (ppb)

Blank indicates compound was not detected

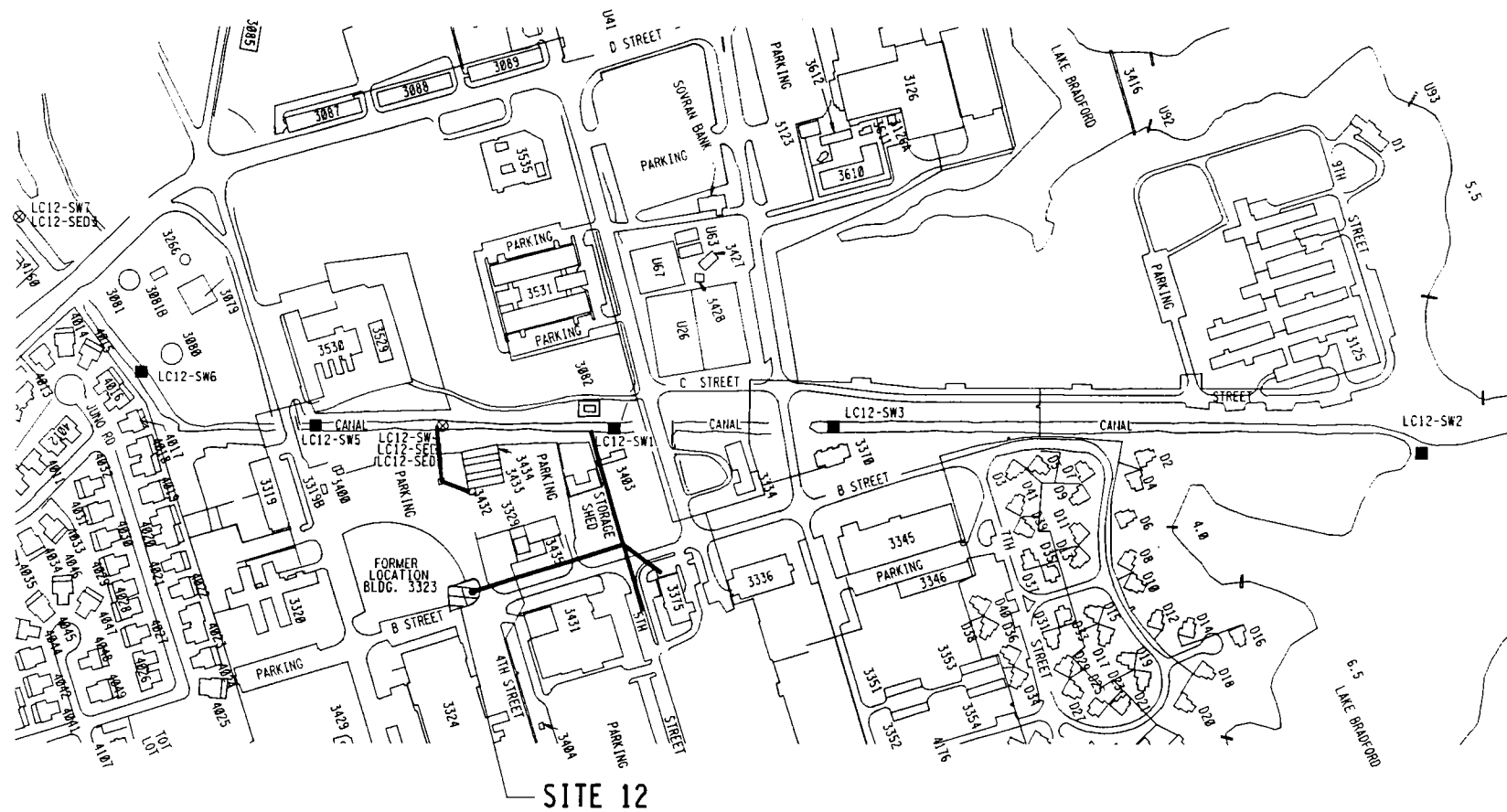
TABLE 2-4

SUMMARY OF ANALYTICAL RESULTS FOR GROUNDWATER SAMPLES  
 SITE 12: EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAB LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 PHASE II ENVIRONMENTAL SITE STUDY  
 MARCH 1991

PARAMETER	LCWW-1	LCWW-2	LCWW-3	LCWW-4	LCWW-5	LCWW-6	LCWW-7	LCWW-8	LCWW-9	LCWW-10	LCWW-11	LCWW-12
<b>VOLATILE ORGANIC COMPOUNDS</b>												
1,1,1-TRICHLOROETHENE	1.1		0.34							0.34		
TRICHLOROETHENE		180		6.5		2.5	13		30	2.8	1.5	100
TETRACHLOROETHENE		470		4.0					160	4.7		230
CHLOROFORM				0.20	1.6	0.13	0.15	1.7	2.1	0.57	47	0.72
DICHLORODIFLUOROMETHANE							130					
VINYL CHLORIDE										210		
TRANS-1,2-DICHLOROETHENE										9.9		
BROMODICHLOROMETHANE											12	

**NOTES:**

All results in parts per billion (ppb)  
 Blank indicates compound was not detected



SITE 12

**LEGEND**

- ⊗ SURFACE WATER AND SEDIMENT SAMPLING LOCATION
- SURFACE WATER SAMPLING LOCATION
- DRAINAGE LINE

0 500'  
SCALE IN FEET

SOURCE: DRAFT INTERIM REMEDIAL INVESTIGATION REPORT, EBASCO, 5/91

**FIGURE 2-5  
PREVIOUS SAMPLING LOCATIONS  
SITE 12  
INTERIM REMEDIAL INVESTIGATION  
NAB - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**



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TABLE 2-5

SUMMARY OF ANALYTICAL RESULTS FOR SURFACE WATER AND SEDIMENT SAMPLES  
SITE 12: EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
NAB LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA  
INTERIM REMEDIAL INVESTIGATION  
NOVEMBER 1991

PARAMETER	LC12-SW1	LC12-SW2	LC12-SW3	LC12-SW4	LC12-SW5	LC12-SW6	LC12-SW7	LC12-SED1	LC12-SED2	LC12-SED3
VOLATILE ORGANIC COMPOUNDS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

## NOTES:

All results in parts per billion (ppb)

ND indicates compound was not detected

processes. Specific mechanisms to account for the reduction in contamination in the canal include volatilization, dilution, and biodegradation. Periodic flushing of the canal occurs during heavy precipitation events and overflows of Lake Bradford. These flushings could remove contaminated surface water and, if the flow rate is great enough, contaminated sediment as well.

The IRI recommended delineation of the area of volatile organic contamination. Once this had been defined, various remedial alternatives, such as no-action, containment, and treatment, could be evaluated.

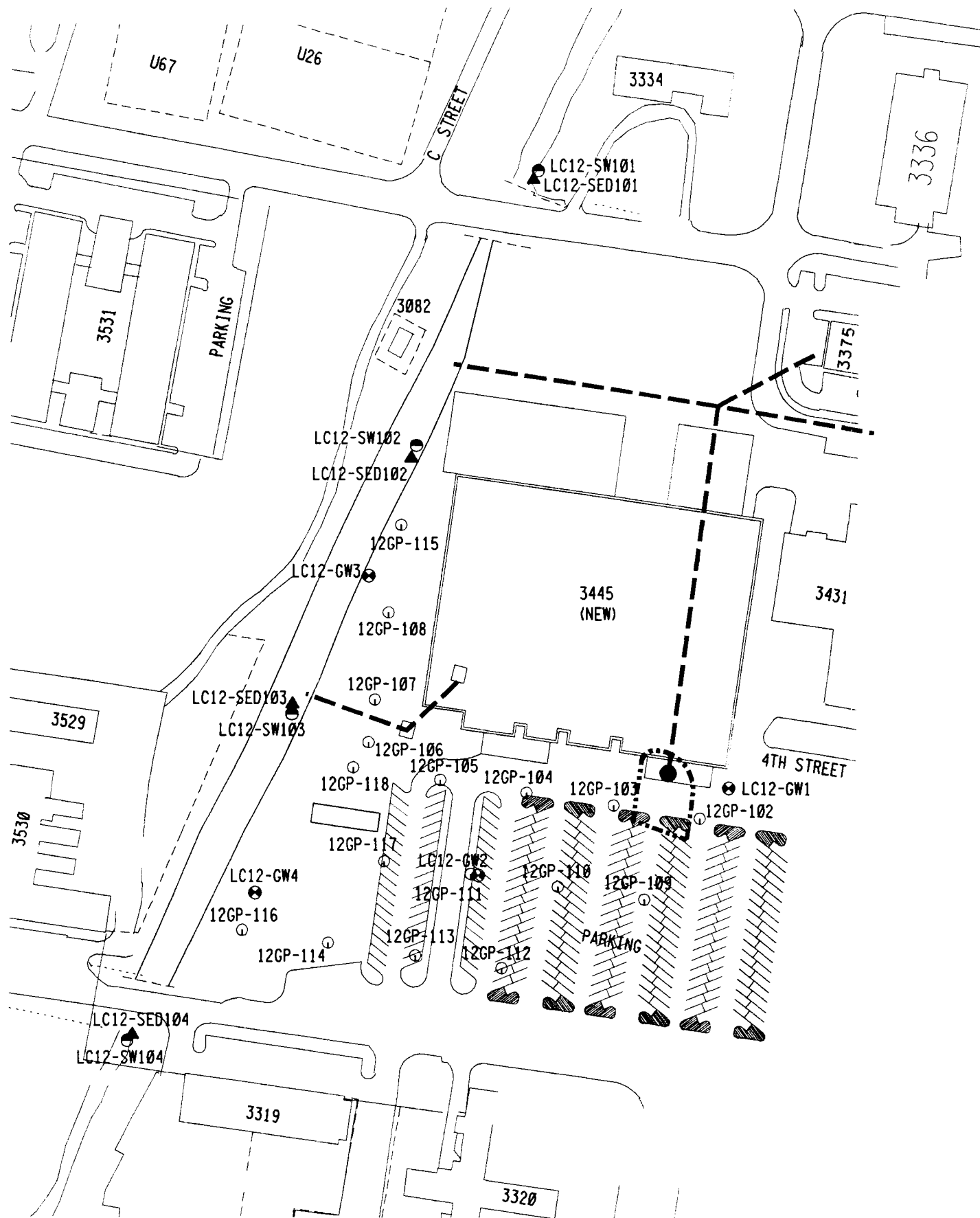
**Site Characterization** A subsurface investigation evaluated the lateral and vertical extent of potentially contaminated environmental media at the site. Soil borings were drilled in proximity to the location of the former USTs, and each boring was converted into a monitoring well. Soil and groundwater samples from the borings and wells were analyzed to evaluate the extent of contamination. Tetrachloroethane was detected in the soil samples at concentrations ranging from 4  $\mu\text{g/kg}$  to 120  $\mu\text{g/kg}$ . Trace levels of TPH were detected in three of the groundwater samples at concentrations ranging from 30  $\mu\text{g/l}$  to 250  $\mu\text{g/l}$ , well below the Virginia Water Quality Standard of 1,000  $\mu\text{g/l}$ . A geophysical investigation and soil gas survey also were conducted to identify potential contaminated areas of concern for subsequent sampling. The geophysical data indicated the presence of existing utilities and buried metal objects from the demolition at the site. The soil gas survey indicated the presence of tetrachloroethane, primarily in the southeast corner of the site. The Site Characterization recommended the installation of a passive soil gas reduction system with a liner to reduce the possibility of vapor migration into the proposed new building, and the removal of the storm sewer.

**RI/FS** As part of the RI effort completed by FWES at NAB Little Creek in the summer of 1993, a Geoprobe® investigation was conducted and four monitoring wells were subsequently installed at Site 12. In addition, groundwater, surface water, and sediment samples were collected and analyzed during this investigation. The sampling locations are presented on **Figure 2-6**.

Four groundwater samples were collected from the four groundwater monitoring wells at Site 12 and were analyzed for VOCs. Toluene, 1,2-dichloroethene (total), trichloroethane, and tetrachloroethane were among the VOCs detected in surface water samples at Site 12. The highest total VOCs were 18,200  $\mu\text{g/L}$  at 12-GW-102. **Table 2-6** presents a summary of this data.

Four surface water samples were collected from the stream adjacent to Site 12. These samples were analyzed for VOCs and TAL metals. The highest total VOCs was 144  $\mu\text{g/L}$  at 12-SW-102. **Table 2-7** presents a summary of the surface water VOC data. TAL metals detected at each surface water location include barium, calcium, copper, iron, lead, magnesium, manganese, potassium, sodium, and zinc. Highest TAL metals concentrations were detected at 12-SW-102. **Table 2-8** presents a summary of the TAL metals data.

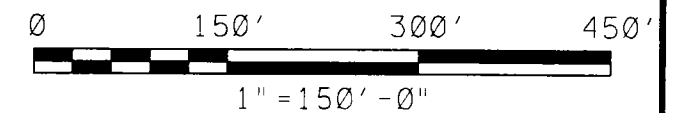
Four sediment samples were collected at Site 12; two from the location of 12-SW-102 at depths from 0-6 inches and 6-12 inches, and two from the location of 12-SW-103 at the same depths. These samples were analyzed for VOCs, TAL metals, and TOC. VOCs were detected in all of the sediment samples. 1,2-dichloroethene (total), trichloroethane, and tetrachloroethane were among the VOCs detected, with the highest concentrations of these compounds at 12-SW-102 at the 0-6 inch depth. The highest total VOCs detected was 82  $\mu\text{g/L}$  at 12-SW-102 at the 6-12 inch depth. **Table 2-9** presents a summary of the VOC



## LEGEND

- FORMER WATER AND STORM SEWER LINE
- SITE BOUNDARY
- ⊙ GEOPROBE
- 12GP-103 ⊙ MONITORING WELL INSTALLED BY FWES
- LC12-GW4 ⊙ SURFACE WATER SAMPLE
- LC12-SW104 ▲ SEDIMENT
- SED104

## GRAPHIC SCALE



REV.	DATE	DESCRIPTION	APPR.
REVISIONS			
FIGURE 2-6			
PREVIOUS SAMPLING LOCATIONS			
FWES RI/FS			
SITE 12			
NAB - LITTLE CREEK			
VIRGINIA BEACH, VIRGINIA			
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CHECKED BY:			DRAWING No.
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TABLE 2-6

**SUMMARY OF VOLATILE ORGANIC COMPOUNDS  
 DETECTED IN GROUNDWATER SAMPLES  
 AND ASSOCIATED QUALITY CONTROL SAMPLES  
 SITE 12 - EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 JUNE 28, 1993**

SAMPLE LOCATION/NUMBER SAMPLE MATRIX UNITS	12-GW-101 Water ug/L	12-GW-102 Water ug/L	12-GW-103 Water ug/L	12-GW-104 Water ug/L
<b>VOLATILE ORGANIC COMPOUNDS (VOCs):</b>				
1,2-Dichloroethene (total)	ND	11,000	2 J	ND
Chloroform	ND	ND	1 J	ND
Trichloroethene	ND	2,300	2 J	2 J
Tetrachloroethene	ND	4,900	4 J	2 J
<b>TOTAL VOCs:</b>	ND	18,200	9 J	4 J
<b>TOTAL TICs:</b>	ND	ND	ND	ND

**NOTES:**

ND indicates compound was not detected

ug/L indicates micrograms per liter

J indicates an estimated value

TICs indicates tentatively identified compounds

Trip Blank is shared with Site 13

Equipment Rinsate and Field Blank shared with the Background Well samples

TABLE 2-7

**SUMMARY OF VOLATILE ORGANIC COMPOUNDS  
 DETECTED IN SURFACE WATER SAMPLES  
 AND ASSOCIATED QUALITY CONTROL SAMPLES  
 SITE 12 - EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 JUNE 28, 1993**

SAMPLE LOCATION/NUMBER SAMPLE MATRIX UNITS	12-SW-101 Water ug/L	12-SW-102 Water ug/L	12-SW-103 Water ug/L	12-SW-104 Water ug/L
<b>VOLATILE ORGANIC COMPOUNDS (VOCs):</b>				
Acetone	ND	50 B	31 B	20 B
1,2-Dichloroethene (total)	ND	ND	11	ND
2-Butanone	ND	36	ND	ND
Trichloroethene	ND	ND	3 J	ND
Tetrachloroethene	ND	ND	3 J	ND
Toluene	4 J	58	2 J	ND
<b>TOTAL VOCs:</b>	4 J	144	50 J	20
<b>TOTAL TICs:</b>	ND	7 J	ND	ND

**NOTES:**

ND indicates compound was not detected

ug/L indicates micrograms per liter

J indicates an estimated value

B indicates compound detected in lab blank

TICs indicates tentatively identified compounds

Equipment rinsate, field blank, and trip blank shared with Background Well samples

Matrix spike/matrix spike duplicate (MS/MSD) shared with Site 10

TABLE 2-8

**SUMMARY OF TAL METALS  
 DETECTED IN SURFACE WATER SAMPLES  
 AND ASSOCIATED QUALITY CONTROL SAMPLES  
 SITE 12 - EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 JUNE 28, 1993**

SAMPLE LOCATION/NUMBER SAMPLE MATRIX UNITS	12-SW-101 Water ug/L	12-SW-102 Water ug/L	12-SW-103 Water ug/L	12-SW-104 Water ug/L
<b>TAL METALS:</b>				
Aluminum	4,320 J	81,800 J	ND	ND
Arsenic	2.8 J	23.4 J	ND	2.2 J
Barium	50.4 J	669 J	25.6 J	25.3 J
Beryllium	ND	3.1 J	ND	ND
Cadmium	ND	7.5 J	ND	ND
Calcium	15,700 J	84,500 J	16,400 J	15,600 J
Chromium	ND	148 J	ND	ND
Cobalt	ND	64.0 J	ND	ND
Copper	21.5 J	305 J	10.1 J	4.7 J
Iron	10,300 J	94,800 J	3,930 J	2,900 J
Lead	25.2 J	312 J	2.0 J	3.0 J
Magnesium	5,300 J	26,600 J	5,150 J	6,160 J
Manganese	547 J	1,240 J	507 J	529 J
Mercury	ND	0.79 J	ND	ND
Nickel	ND	143 J	ND	ND
Potassium	3,880 J	21,300 J	3,600 J	2,800 J
Sodium	13,700 J	26,200 J	13,300 J	13,400 J
Vanadium	11.8 J	162 J	ND	ND
Zinc	204 J	3,800 J	153 J	39.1 J

**NOTES:**

ND indicates compound was not detected

ug/L indicates micrograms per liter

J indicates an estimated value

Equipment Rinsate and Field Blank shared with Background Well samples

Matrix spike/matrix spike duplicate (MS/MSD) shared with Site 10

TABLE 2-9

**SUMMARY OF VOLATILE ORGANIC COMPOUNDS  
 DETECTED IN SEDIMENT SAMPLES  
 AND ASSOCIATED QUALITY CONTROL SAMPLES  
 SITE 12 - EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 JUNE 28, 1993**

SAMPLE LOCATION/NUMBER SAMPLE DEPTH SAMPLE MATRIX UNITS	12-SED-102-00 0 - 6 inches Sediment ug/kg	12-SED-102-06 6 - 12 inches Sediment ug/kg	12-SED-103-00 0 - 6 inches Sediment ug/kg	12-SED-103-06 6 - 12 inches Sediment ug/kg
<b>VOLATILE ORGANIC COMPOUNDS (VOCs):</b>				
Acetone	30 J	82 J	ND	8 J
1,2-Dichloroethene (total)	14 J	ND	2 J	ND
Trichloroethene	19 J	ND	3 J	ND
Tetrachloroethene	15 J	ND	6 J	ND
Toluene	ND	ND	ND	5 J
Xylene (total)	ND	ND	ND	4 J
<b>TOTAL VOCs:</b>	78 J	82 J	11 J	17 J
<b>TOTAL TICs:</b>	131 J	ND	100 J	228 J

**NOTES:**

ND indicates compound was not detected

ug/kg indicates micrograms per kilogram

J indicates an estimated value

TICs indicates tentatively identified compounds

Equipment rinsate, trip blank, matrix spike/matrix spike duplicate, and duplicate sample shared with Site 13

sediment sampling data. The TAL metals aluminum, arsenic, barium, calcium, chromium, copper, iron, lead, magnesium, manganese, potassium, vanadium, and zinc were detected at all the sediment sample locations and depths. With the exception of lead, the highest levels of these metals were detected at 12-SED-102 at the 0-6 inch depth. Lead was detected at the highest concentration (110 mg/kg) at 12-SED-106 at the 0-6 inch depth. **Table 2-10** presents a summary of the TAL metals sediment sampling data. TOC was detected in all the samples. TOC sediment sampling data is presented in **Table 2-11**.

The RI/FS concluded groundwater contamination (VOCs) was primarily restricted to monitoring well 12-GW-102. The surface water was also an affected media at the site, with the constituents of concern being primarily TAL metals. As a result, the RI/FS recommended additional subsurface soil, groundwater, and surface water sampling at the site, as well as additional hydrologic testing.

#### **2.5.2.2 Site 13--Public Works PCP Dip Tank and Wash Rack**

**Initial Assessment Study** The IAS recommended the installation of five monitoring wells to sample and analyze the groundwater. The sampling of the groundwater was to occur quarterly for one year. In addition, six composite soil samples were to be collected in the open lot between the wash rack and the paved compound where the PCP dip tank and layout yard were located to determine the extent of contamination.

**Round 1 Verification Step** The RVS involved the collection of samples from the area near Site 13, five groundwater and six soil. LC13-S4, LC13-S5, and LC13-S6 were collected at a depth of 0.0 to 0.5 feet. LC13-S1 and LC13-S2 were collected between 0.5 and 2.5 feet, and LC13-S3 was collected between 3.0 and 5.0 feet. Sample locations are shown on **Figure 2-7**. The results of sampling are provided in **Tables 2-12** and **2-13**.

VOCs were detected in four of the groundwater samples at levels ranging from not detected to 21 µg/l. Semi-volatile organic compounds (SVOCs) were detected in four groundwater samples at levels ranging from 1.6 µg/l to 55 µg/l. Oil and grease also were detected in three groundwater samples at levels ranging from not detected to 7,000 µg/l.

VOCs were detected in all six of the soil samples at levels ranging from not detected to 0.38 µg/l. SVOCs were detected in soil samples at levels ranging from not detected to 79 µg/l. Oil and grease also were detected in the soil samples at levels ranging from 115 µg/l to 5,805 µg/l.

The RVS results indicated contamination present in the soil near the location of the former dip tank and is currently leaving the site via groundwater. The source of VOCs in groundwater may not be attributed to the site. The RVS suggested that potential human health risks can be posed by the site contaminants if groundwater from the site is used as a drinking water supply, or if contact is made with the soil beneath the asphalt at the former dip tank location. The RVS recommended a second round of samples be collected from the five monitoring wells.

**Interim Remedial Investigation** The IRI field activities at the Public Works PCP Dip Tank and Wash Rack consisted of the collection and analysis of groundwater samples and water level data from the monitoring wells at the site. A total of five groundwater samples were collected and analyzed. The

TABLE 2-10

**SUMMARY OF TAL METALS  
 DETECTED IN SEDIMENT SAMPLES  
 AND ASSOCIATED QUALITY CONTROL SAMPLES  
 SITE 12 - EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 JUNE 28, 1993**

SAMPLE LOCATION/NUMBER SAMPLE DEPTH SAMPLE MATRIX UNITS	12-SED-102-00 0 - 6 inches Sediment mg/kg	12-SED-102-06 6 - 12 inches Sediment mg/kg	12-SED-103-00 0 - 6 inches Sediment mg/kg	12-SED-103-06 6 - 12 inches Sediment mg/kg
<b>TAL METALS:</b>				
Aluminum	11,700 J	4,180 J	2,690 J	1,130 J
Arsenic	5.6 J	3.8 J	2.1 J	0.64 J
Barium	72.0 J	30.1 J	12.5 J	3.4 J
Cadmium	ND	1.2 J	ND	ND
Calcium	2,970 J	793 J	217 J	72.5 J
Chromium	20.6 J	8.4 J	3.0 J	1.3 J
Cobalt	4.8 J	1.5 J	1.3 J	ND
Copper	36.0 J	18.0 J	7.5 J	2.3 J
Iron	12,900	4,940 J	2,560 J	1,220 J
Lead	66.3	38.3 J	110 J	8.7 J
Magnesium	1,990 J	541 J	274 J	83.6 J
Manganese	144 J	35.2 J	11.7 J	3.7 J
Mercury	ND	ND	0.28 J	ND
Nickel	13.8 J	5.1 J	2.9 J	ND
Potassium	1,350 J	340 J	115 J	45.8 J
Sodium	346 J	ND	ND	ND
Vanadium	26.9 J	11.9 J	8.1 J	1.9 J
Zinc	383 J	233 J	30.1 J	6.1 J

**NOTES:**

ND indicates compound was not detected

mg/kg indicates milligrams per kilogram

J indicates an estimated value

Equipment rinsate, matrix spike/matrix spike duplicate, and duplicate sample shared with Site 13

TABLE 2-11

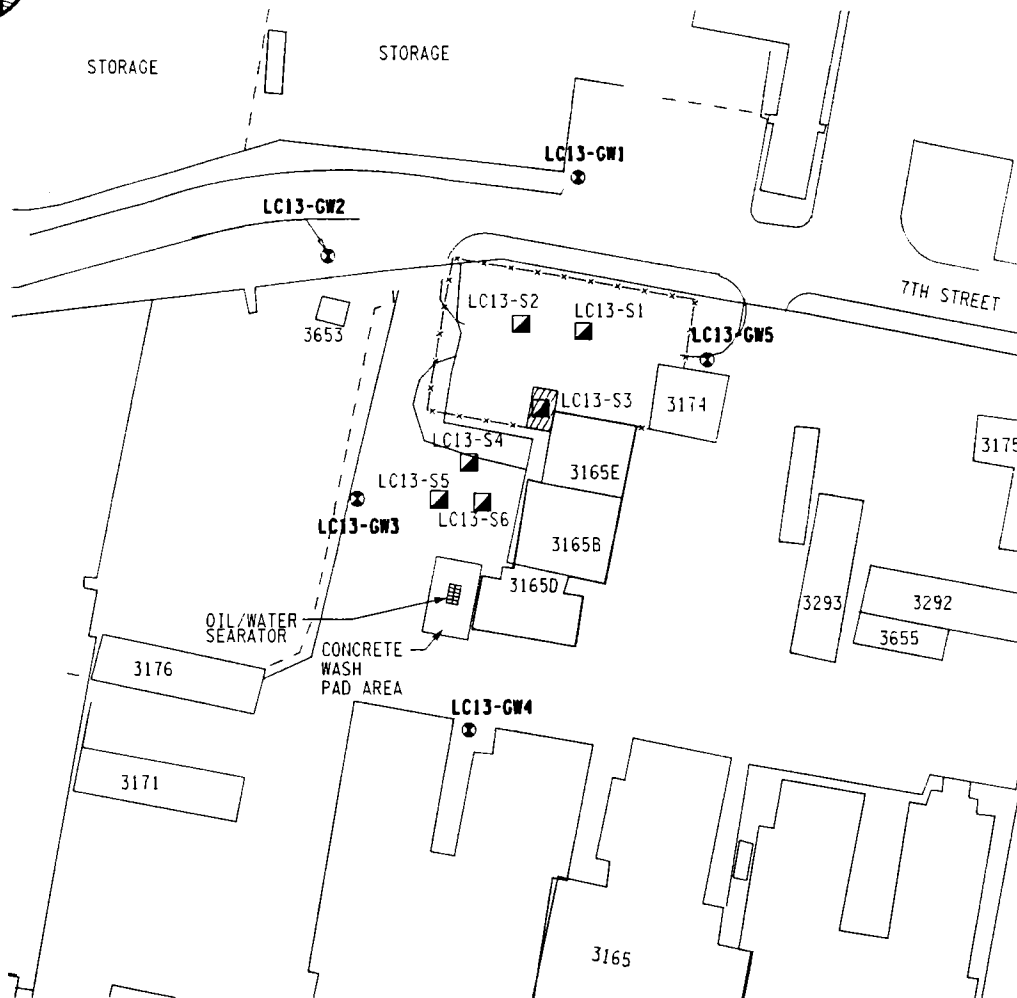
**SUMMARY OF TOTAL ORGANIC CARBON  
 DETECTED IN SEDIMENT SAMPLES  
 AND ASSOCIATED QUALITY CONTROL SAMPLES  
 SITE 12 - EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 JUNE 28, 1993**

SAMPLE LOCATION/NUMBER SAMPLE DEPTH SAMPLE MATRIX UNITS	12-SED-102-00 0 - 6 inches Sediment mg/kg	12-SED-102-06 6 - 12 inches Sediment mg/kg	12-SED-103-00 0 - 6 inches Sediment mg/kg	12-SED-103-06 6 - 12 inches Sediment mg/kg
<b>TOTAL ORGANIC CARBON:</b>	77,000	52,500	5,940	488

**NOTES:**

mg/kg indicates milligrams per kilogram

Equipment rinsate, matrix spike/matrix spike duplicate, and duplicate sample shared with Site 13



### LEGEND



LOCATION OF FORMER PCP DIP TANK

LC13-GW4



MONITORING WELL

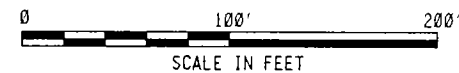
LC13-S1



SOIL SAMPLE



FENCING INDICATES APPROX. DRYING AREA BOUNDARY.



SCALE IN FEET

### FIGURE 2-7 PREVIOUS SAMPLING LOCATIONS SITE 13 ROUND 1 VERIFICATION STEP

NAB - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA



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SOURCE: ROUND 1 VERIFICATION STEP, CH<sub>2</sub>M HILL, 10/86



TABLE 2-12

SUMMARY OF ANALYTICAL RESULTS FOR SOIL SAMPLES  
 SITE 13: PUBLIC WORKS COMPOUND PCP DIP TANK/METALS SHOP  
 NAB LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 ROUND 1 VERIFICATION STEP  
 OCTOBER 1986

PARAMETER	LC13-S1	LC13-S2	LC13-S3	LC13-S4	LC13-S5	LC13-S6
<b>OIL AND GREASE</b>	115	144	1,039	421	5,805	3,726
<b>VOLATILE ORGANIC COMPOUNDS</b>						
METHYLENE CHLORIDE	0.38	0.29	0.05	0.13	0.33	0.4
ACETONE	0.019	0.070	0.077	0.12	0.035	0.024
TOLUENE	0.0028	0.026				
ETHYL BENZENE			0.0016			
TOTAL XYLENES			0.0094			
<b>BASE/NEUTRAL COMPOUNDS</b>						
NAPHTHALENE	NR	NR	8.9	NR	NR	NR
ACENAPHTHALENE	NR	NR	1.2	NR	NR	NR
PHENANTHRENE	NR	NR	4.2	NR	NR	NR
FLUORANTHENE	NR	NR	2.2	NR	NR	NR
PYRENE	NR	NR	3.8	NR	NR	NR
2-METHYLNAPHTHALENE	NR	NR	4.5	NR	NR	NR
1-METHYLNAPHTHALENE	NR	NR	2.3	NR	NR	NR
DI-METHYLNAPHTHALENE	NR	NR	49	NR	NR	NR
TRI-METHYLNAPHTHALENE	NR	NR	34	NR	NR	NR
SATURATED HYDROCARBONS	NR	NR	34	NR	NR	NR
BIS(2-ETHYLHEXYL)PHTHALATE	NR	NR		11	NR	NR
<b>ACID EXTRACTABLE COMPOUNDS</b>						
PENTACHLOROPHENOL		79				

**NOTES:**

All results in parts per million (ppm)

Black indicates compound was not detected

NR indicates results were reported only if observed

TABLE 2-13

**SUMMARY OF ANALYTICAL RESULTS FOR GROUNDWATER SAMPLES**  
**SITE 13: PUBLIC WORKS COMPOUND PCP DIP TANK/METALS SHOP**  
**NAB LITTLE CREEK**  
**VIRGINIA BEACH, VIRGINIA**  
**ROUND 1 VERIFICATION STEP**  
**OCTOBER 1986**

PARAMETER	LC13-GW1	LC13-GW2	LC13-GW3	LC13-GW4	LC132-GW5
<b>OIL AND GREASE</b>	7,000		7,000		7,000
<b>VOLATILE ORGANIC COMPOUNDS</b>					
METHYLENE CHLORIDE					6.4
TRICHLOROETHENE	8.5		7.7	16	15
TRANS-1,2-DICHLOROETHENE			8.9		
TETRACHLOROETHENE			14	21	
CHLOROBENZENE				6.7	
<b>BASE/NEUTRAL COMPOUNDS</b>					
BIS(2-ETHYLHEXYL)PHTHALATE		27			
1,4-DICHLOROBENZENE				2.1	
1,2-DICHLOROBENZENE				2.4	
<b>ACID EXTRACTABLE COMPOUNDS</b>					
PENTACHLOROPHENOL		55	17	8.1	
PHENOL					1.6

**NOTES:**

All results in parts per billion (ppb)

Blank indicates compound was not detected

sample locations are indicated on **Figure 2-8**. The results of sampling are provided in **Table 2-14**. The data generated by these activities were used to determine groundwater circulation patterns and whether the site has impacted groundwater quality in the area.

VOCs were detected only in LC13-GW4, while base neutral compounds were detected only in LC13-GW2. TPH were not detected in any of the five groundwater samples. Metals were detected in all five groundwater samples.

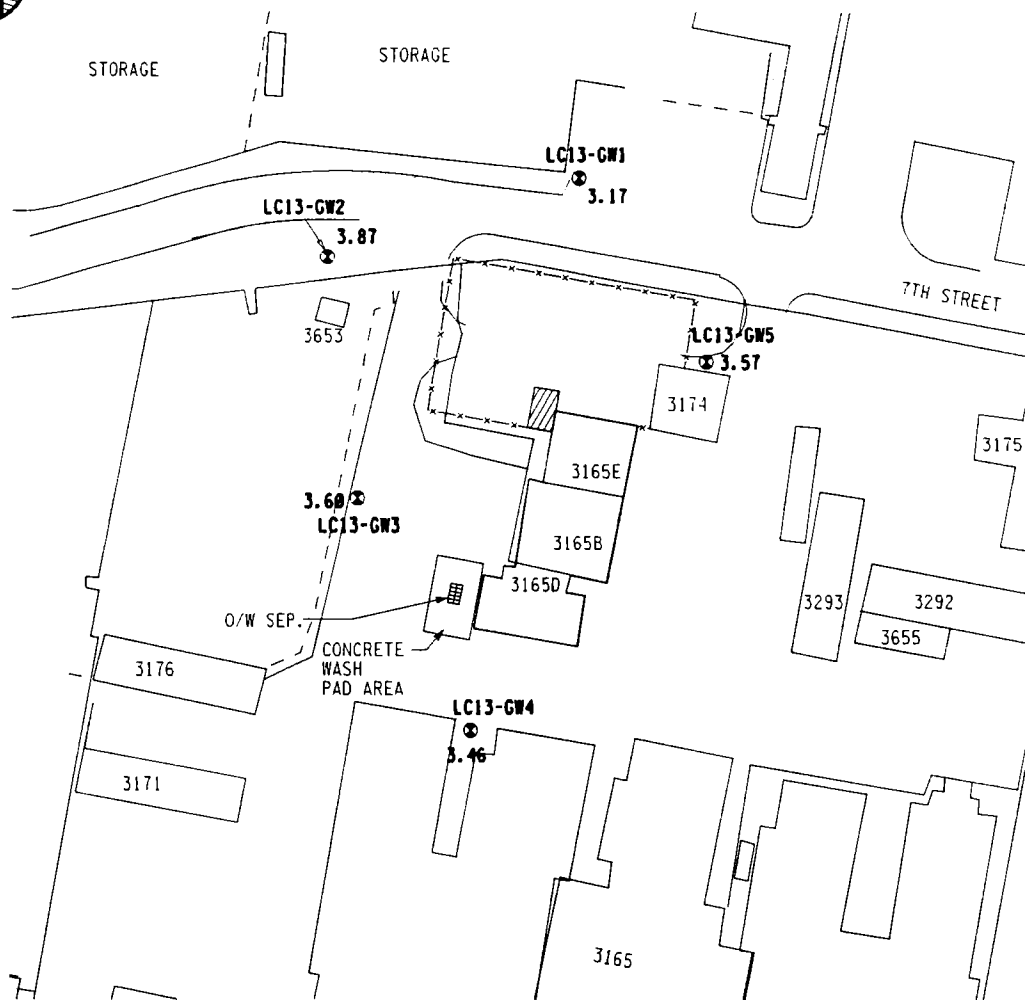
Water level data were collected from the five monitoring wells at Site 13 in December 1990 and March 1991. Groundwater flow at the PCP Dip Tank changed markedly between January and March 1991. In January, the direction of flow was south-southeast. In March, the elevation of the water table declined significantly in well LC13-GW2, resulting in both southward and northward components of flow. The reasons for this reversal in direction are not known, but may be related to precipitation or seasonal variations. The need for additional water level measurements was identified to support a more definitive explanation of the observed trend.

The presence of increasing concentrations of PCP in well LC13-GW1 between 1986 and 1990 suggested the source of PCP contamination is still active. The occurrence of PCP in wells LC13-GW2 and LC13-GW3, both of which are west of the former dip tank and drying yard location, supported earlier interpretations regarding the highly variable nature of groundwater flow at the site, including occasional reversals in the direction of flow. PCP contamination in well LC13-GW4, located south-southeast of the former dip tank location, was attributed to the southward gradient that had also been documented for the site.

Volatile organic contamination detected in well LC13-GW4 indicated the source of contamination at the site was still active. The probable source of this contamination was identified as leaky drains and/or sewer lines located adjacent to Building 3165, or the oil/water separator that lies beneath the driveway, midway between well LC13-GW4 and the wash rack. The use of TCE and other solvents on the wash rack would have resulted in temporary storage in the separator. A sustained release from the separator would have created a relatively significant volume of contaminated soil. A similar situation would have been created if the source was leaky sewer lines beneath Building 3165.

The extent of volatile organic contamination decreased considerably between 1986 and 1990. The decline in TCE concentrations between 1986 and 1990 in wells LC13-GW1, LC13-GW3, and LC13-GW5 was most likely due to the on-going depletion of the source. This depletion would be expected considering TCE and other chlorinated solvents are no longer used at the wash rack or in Building 3165. Fluctuations in the gradient and direction of groundwater flow, as observed with the December 1990 and March 1991 water level data, appear to occur regularly and have probably minimized migration of contamination in any one direction.

The IRI recommended groundwater monitoring should continue at Site 13 to confirm a natural clean-up of the aquifer is occurring. However, no additional remedial response was recommended unless the current land use changes or human and/or environmental receptors are identified.



### LEGEND



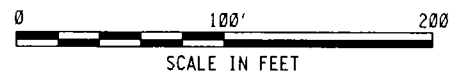
LOCATION OF FORMER PCP DIP TANK

LC13-GW4

3.46

MONITORING WELL, WITH WATER LEVEL, FEET M.S.L.

-x-x-x- FENCING INDICATES APPROX. DRYING AREA BOUNDARY.



SCALE IN FEET

FIGURE 2-8  
PREVIOUS SAMPLING LOCATIONS  
SITE 13  
INTERIM REMEDIAL INVESTIGATION  
NAB - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA



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SOURCE: DRAFT INTERIM REMEDIAL INVESTIGATION REPORT, EBASCO, 5/91

TABLE 2-14

SUMMARY OF ANALYTICAL RESULTS FOR GROUNDWATER SAMPLES  
 SITE 13: PUBLIC WORKS COMPOUND PCP DIP TANK/METALS SHOP  
 NAB LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 INTERIM REMEDIAL INVESTIGATION  
 NOVEMBER 1991

PARAMETER	LC13-GW1	LC13-GW2	LC13-GW3	LC13-GW4	LC13-GW5
<b>VOLATILE ORGANIC COMPOUNDS (ug/l)</b>					
TOLUENE				3 J	
TETRACHLOROETHENE				4 J	
TRANS-1,2-DICHLOROETHENE				5 J	
TETRACHLOROETHENE				4 J	
CHLOROFORM				7	
<b>TOTAL PETROLEUM HYDROCARBONS (mg/l)</b>					
<b>BASE/NEUTRAL AND ACID EXTRACTABLE COMPOUNDS (ug/l)</b>					
NAPHTHALENE		3 J			
2-METHYLNAPHTHALENE		1 J			
PENTACHLOROPHENOL		130			
<b>METALS (ug/l)</b>					
BERYLLIUM	2		4		2
CADMIUM	11	7	13	7	138
CHROMIUM (TOTAL)	56	64	78	46	64
COPPER	85		96		93
LEAD	23	17	33	19	44
MERCURY	0.3			0.3	
NICKEL	40		24		32
THALLIUM		44	4.1		
ZINC	169	98	189	75	648 J
ALUMINUM	70,800	68,900	168,000	57,400	96,900
BARIUM	268	197	448	165	322
CALCIUM	39,600	11,400	11,000	28,100	8,930
COBALT	33	16	28		96
IRON	77,800	75,800	164,000	39,850	12,000
MAGNESIUM	12,100	9,370	16,500	12,200	10,700 J
MANGANESE	1,810	673	772	1,180	954
POTASSIUM	9,140	5,560	11,000	8,650	7,650
SODIUM	26,500	17,900	18,900	19,600	14,700
VANADIUM	86		200		82

**NOTES:**

All results in parts per billion (ppb)  
 Blank indicates compound was not detected  
 J indicates an estimated concentration

RI/FS As part of the RI effort completed by FWES at NAB Little Creek in the summer of 1993, three new monitoring wells were installed. In addition, groundwater, surface, and subsurface soil samples were collected and analyzed during this investigation. The sampling locations are shown on **Figure 2-9**.

Five surface soil samples were collected from the former location of the pentachlorophenol dip tank and a drainage ditch on-site. These samples were collected from a depth of 0 to 6 inches below ground surface and analyzed for VOCs, SVOCs, and TOC. VOCs were detected at all five surface soil sampling locations. Acetone and toluene were among the VOCs detected at the surface soil sampling locations. The highest total VOCs detected was 19  $\mu\text{g/kg}$  at 13-SS-104. **Table 2-15** presents a summary of VOCs detected in surface soil samples at Site 13. SVOCs were detected at all five surface soil sampling locations. The highest concentrations of SVOC compounds were detected at the 13-SS-103 sampling location. Total SVOCs detected ranged from 1,210  $\mu\text{g/kg}$  (J) at 13-SS-102 to 95,800  $\mu\text{g/kg}$  (J) at 13-SS-106 (duplicate of 13-SS-103). **Table 2-16** presents a summary of SVOCs detected in surface soil samples at Site 13. TOC was detected at all five of the surface soil sampling locations at Site 13. **Table 2-17** presents a summary of TOC detected in surface soil samples and associated quality control samples.

Three subsurface soil samples were collected at varying depths from the soil boring which was converted to monitoring well LC13-GW08. These samples were analyzed for VOCs, SVOCs, and TOC. VOCs were detected at two of the three subsurface soil sampling locations. Xylene (total), acetone, and ethylbenzene were among the VOCs detected. The highest total VOCs was 250  $\mu\text{g/kg}$  (J) at 13-SB-108-01. **Table 2-18** presents a summary of the subsurface soil VOC analytical data. SVOCs were detected at all three subsurface soil sampling locations. Pentachlorophenol was detected at all three subsurface soil sampling locations; concentrations detected ranged from 11,000  $\mu\text{g/kg}$  at 13-SB-108-02 to 890,000  $\mu\text{g/kg}$  at 13-SB-108-01. 2-methylnaphthalene was detected at two of the three subsurface soil sampling locations; the highest concentration detected was 6,300  $\mu\text{g/kg}$  (J) at 13-SB-108-03. Naphthalene and bis(2-ethylhexyl)phthalate were each detected only at 13-SB-108-02 at concentrations of 85  $\mu\text{g/kg}$  (J) and 55  $\mu\text{g/kg}$  (J), respectively. Total concentrations of SVOCs detected ranged from 11,260  $\mu\text{g/kg}$  (J) at 13-SB-108-02 to 890,000  $\mu\text{g/kg}$  at 13-SB-108-01. **Table 2-19** presents a summary of SVOCs detected in subsurface soil. TOC was detected at all three subsurface soil sampling locations. **Table 2-20** presents a summary of TOC detected in subsurface soil samples at Site 13.

Six groundwater samples were collected from monitoring wells at Site 13. These samples were analyzed for VOCs and SVOCs. VOCs were detected at all six groundwater sampling locations. Total VOCs ranged in concentration from 1  $\mu\text{g/l}$  (J) at 13GW07 to 262  $\mu\text{g/l}$  (J) at 13GW06. Trichloroethane, chlorobenzene, and tetrachloroethane were detected at their highest concentrations, 5  $\mu\text{g/L}$ , 110  $\mu\text{g/L}$ , and 7  $\mu\text{g/L}$ , respectively, at 13GW04. The highest concentration of vinyl chloride detected was 200  $\mu\text{g/l}$  at 13GW06. The highest concentration of ethylbenzene detected was 15  $\mu\text{g/l}$  at 13GW05. The highest concentration of xylene (total) detected was 77  $\mu\text{g/l}$  at 13GW09 (duplicate of 13GW08). The highest concentration of total VOCs was 262  $\mu\text{g/l}$  (J) at 13GW06. **Table 2-21** presents a summary of VOCs detected in groundwater samples at Site 13. SVOCs were detected at four of the six groundwater sampling locations. Pentachlorophenol was detected at three of the six groundwater sampling locations; the highest concentration detected was 1,700  $\mu\text{g/l}$  at 13GW08. Naphthalene was detected at two of the six groundwater sampling locations; the highest concentration detected was 96  $\mu\text{g/l}$  (J) at 13GW08. **Table 2-22** presents a summary of SVOCs detected in groundwater samples and associated quality control samples at Site 13.



STORAGE

STORAGE

LC13-GW1

LC13-GW2 13SS-104

13SS-105

LC13-GW5 7TH STREET

SITE 13

3653

13SS-103

13SS-101

3174

13SS-102

LC13-GW8

3165E

3175

LC13-GW3

3165B

3165D

O/W SEP.

CONCRETE WASH PAD AREA

LC13-GW7

3293

3292

3655

LC13-GW6

LC13-GW4

3165

## LEGEND



LOCATION OF FORMER  
PCP DIP TANK



SITE BOUNDARY



EXISTING MONITORING WELL

LC13-GW1



MONITORING WELL INSTALLED  
BY FWES

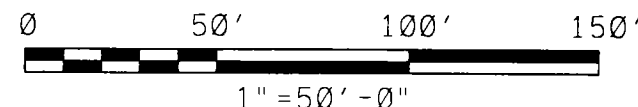
LC13-GW5



SURFACE SOIL SAMPLES

13SS-104

## GRAPHIC SCALE



REV.	DATE	DESCRIPTION	APPR.
------	------	-------------	-------

### REVISIONS

FIGURE 2-9

PREVIOUS SAMPLING LOCATIONS

FWES RI/FS

SITE 13

NAB - LITTLE CREEK

VIRGINIA BEACH, VIRGINIA



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CHECKED BY:			DRAWING No.
APPROVED BY:			0247-4-48-1301

CAD REV. No  
02 28-OCT-93

fwesd4.ref

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TABLE 2-15

**SUMMARY OF VOLATILE ORGANIC COMPOUNDS  
 DETECTED IN SURFACE SOIL SAMPLES  
 AND ASSOCIATED QUALITY CONTROL SAMPLES  
 SITE 13 - PUBLIC WORKS PCP DIP TANK AND WASH RACK  
 NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 MAY 13, 1993**

SAMPLE LOCATION/NUMBER	13-SS-101	13-SS-102	13-SS-103	13-SS-106 (Duplicate 13-SS-103)	13-SS-104	13-SS-105
SAMPLE MATRIX UNITS	Soil ug/kg	Soil ug/kg	Soil ug/kg	Soil ug/kg	Soil ug/kg	Soil ug/kg
<b>VOLATILE ORGANIC COMPOUNDS (VOCs):</b>						
Acetone	8 J	8 J	13	ND	19	ND
Toluene	2 J	ND	3 J	3 J	ND	ND
<b>TOTAL VOCs:</b>	10 J	8 J	16 J	3 J	19	ND
<b>TOTAL TICs:</b>	ND	ND	ND	7 J	ND	ND

**NOTES:**

ND indicates compound was not detected

ug/kg indicates micrograms per kilogram

J indicates an estimated value

TICs indicates tentatively identified compounds

Equipment rinsate, field blank, matrix spike/matrix spike duplicate, and trip blank shared with Site 11



TABLE 2-16

**SUMMARY OF SEMI-VOLATILE ORGANIC COMPOUNDS  
DETECTED IN SURFACE SOIL SAMPLES  
AND ASSOCIATED QUALITY CONTROL SAMPLES  
SITE 13 - PUBLIC WORKS PCP DIP TANK AND WASH RACK  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA  
MAY 13, 1993**

SAMPLE LOCATION/NUMBER	13-SS-101	13-SS-102	13-SS-103	13-SS-106 (Duplicate 13-SS-103)	13-SS-104	13-SS-105	11-SS-ER	11-FB-101
SAMPLE MATRIX UNITS	Soil ug/kg	Soil ug/kg	Soil ug/kg	Soil ug/kg	Soil ug/kg	Soil ug/kg	Water ug/L	Water ug/L
<b>SEMI-VOLATILE ORGANIC COMPOUNDS (SVOCs):</b>								
Naphthalene	ND	ND	ND	ND	ND	ND	1 J	ND
2-Methylnaphthalene	410 J	ND	ND	ND	ND	ND	ND	ND
Acenaphthene	950 J	ND	ND	ND	ND	ND	ND	ND
Dibenzofuran	870 J	ND	ND	ND	ND	ND	ND	ND
Fluorene	1,300 J	ND	ND	ND	ND	ND	ND	ND
Pentachlorophenol	2,400	ND	13,000	13,000	520 J	5,500	ND	ND
Phenanthrene	7,900	81 J	820 J	970 J	240 J	ND	ND	ND
Anthracene	1,800 J	ND	ND	ND	ND	ND	ND	ND
Fluoranthene	5,900 J	120 J	4,500	9,800	360 J	ND	ND	ND
Carbazole	1,200 J	ND	ND	ND	ND	ND	ND	ND
Pyrene	9,500	420 J	ND	21,000	1,600	410 J	ND	ND
Butylbenzylphthalate	ND	38 J	ND	ND	44 J	ND	ND	ND
Benzo (a) anthracene	5,000	110 J	5,700	10,000	420	ND	ND	ND
Chrysene	3,100	120 J	7,200	10,000	450	ND	ND	ND
bis (2-Ethylhexyl) phthalate	ND	ND	550 J	630 J	230 J	230 J	6 J	ND
Benzo (b) fluoranthene	3,800	140 J	8,800	13,000	520 J	210 J	ND	ND
Benzo (k) fluoranthene	1,600 J	81 J	1,200 J	3,400 J	170 J	ND	ND	ND
Benzo (a) pyrene	2,800	100 J	3,900	6,400	320 J	ND	ND	ND
Indeno (1,2,3-cd) pyrene	2,400	ND	2,300 J	4,000 J	200 J	ND	ND	ND
Dibenzo (a,h) anthracene	700 J	ND	ND	ND	ND	ND	ND	ND
Benzo (g,h,i) perylene	2,000	ND	2,100 J	3,600 J	190 J	ND	ND	ND
<b>TOTAL SVOCs:</b>	53,630 J	1,210 J	50,070 J	95,800 J	5,264 J	6,350 J	7 J	ND
<b>TOTAL TICs:</b>	9,040 J	2,450 J	11,700 J	14,300 J	3,600 J	3,160 J	38 J	ND

**NOTES:**

ND indicates compound was not detected

ug/kg indicates micrograms per kilogram

ug/L indicates micrograms per liter

J indicates an estimated value

TICs indicates tentatively identified compounds

ER indicates equipment rinsate blank

FB indicates field blank

Matrix spike/matrix spike duplicate (MS/MSD) sample shared with Site 11

TABLE 2-17

**SUMMARY OF TOTAL ORGANIC CARBON  
 DETECTED IN SURFACE SOIL SAMPLES  
 AND ASSOCIATED QUALITY CONTROL SAMPLES  
 SITE 13 - PUBLIC WORKS PCP DIP TANK AND WASH RACK  
 NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 MAY 13, 1993**

SAMPLE LOCATION/NUMBER	13-SS-101	13-SS-102	13-SS-103	13-SS-106 (Duplicate 13-SS-103)	13-SS-104	13-SS-105
SAMPLE MATRIX UNITS	Soil mg/kg	Soil mg/kg	Soil mg/kg	Soil mg/kg	Soil mg/kg	Soil mg/kg
TOTAL ORGANIC CARBON:	51,700 J	14,200 J	21,200 J	55,700 J	7,060 J	15,100 J

**NOTES:**

ND indicates compound was not detected

mg/kg indicates milligrams per kilogram

J indicates an estimated value

Equipment rinsate, field blank, and matrix spike/matrix spike duplicate shared with Site 11

TABLE 2-18

**SUMMARY OF VOLATILE ORGANIC COMPOUNDS  
 DETECTED IN SUBSURFACE SOIL SAMPLES  
 AND ASSOCIATED QUALITY CONTROL SAMPLES  
 SITE 13 - PUBLIC WORKS PCP DIP TANK AND WASH RACK  
 NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 JUNE 28, 1993**

SAMPLE LOCATION/NUMBER	13-SB-108-01 <sup>(1)</sup>	13-SB-108-02	13-SB-109-02 (Duplicate 13-SB-109-02)	13-SB-108-03	13-SB-RB-101	13-SB-RB-102	TB-P2-101
SAMPLE MATRIX UNITS	Soil ug/kg	Soil ug/kg	Soil ug/kg	Soil ug/kg	Water ug/L	Water ug/L	Water ug/L
<b>VOLATILE ORGANIC COMPOUNDS (VOCs):</b>							
Acetone	130 J	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	2 J	ND
Trichloroethene	ND	ND	ND	ND	ND	6 J	ND
Ethylbenzene	ND	ND	ND	17 J	ND	ND	ND
Xylene (total)	120	ND	ND	190	ND	ND	ND
<b>TOTAL VOCs:</b>	250 J	ND	ND	207 J	ND	8 J	ND
<b>TOTAL TICs:</b>	20,355 J	244 J	51 J	17,365 J	ND	ND	ND

**NOTES:**

ND indicates compound was not detected

ug/kg indicates micrograms per kilogram

ug/L indicates micrograms per liter

J indicates an estimated value

TICs indicates tentatively identified compounds

(1) indicates a matrix spike/matrix spike duplicate (MS/MSD) sample was collected with this sample.

RB indicates equipment rinsate blank

TB indicates trip blank

TABLE 2-19

SUMMARY OF SEMI-VOLATILE ORGANIC COMPOUNDS  
DETECTED IN SUBSURFACE SOIL SAMPLES  
AND ASSOCIATED QUALITY CONTROL SAMPLES  
SITE 13 - PUBLIC WORKS PCP DIP TANK AND WASH RACK  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA  
JUNE 28, 1993

SAMPLE LOCATION/NUMBER	13-SB-108-01 <sup>(1)</sup>	13-SB-108-02	13-SB-109-02 (Duplicate 13-SB-108-02)	13-SB-108-03	13-SB-RB-101	13-SB-RB-102
SAMPLE MATRIX UNITS	Soil ug/kg	Soil ug/kg	Soil ug/kg	Soil ug/kg	Water ug/L	Water ug/L
<b>SEMI-VOLATILE ORGANIC COMPOUNDS (SVOCs):</b>						
Naphthalene	ND	85 J	ND	ND	ND	ND
2-Methylnaphthalene	ND	120 J	ND	6,300 J	ND	ND
3-Nitroaniline	ND	ND	ND	ND	ND	R
Pentachlorophenol	890,000	11,000	30,000	89,000	ND	ND
bis (2-Ethylhexyl) phthalate	ND	55 J	ND	ND	ND	ND
<b>TOTAL SVOCs:</b>	890,000	11,260 J	30,000	95,300 J	ND	ND
<b>TOTAL TICs:</b>	130,000 J	26,472 J	R	99,900 J	8 J	ND

**NOTES:**

ND indicates compound was not detected

ug/kg indicates micrograms per kilogram

ug/L indicates micrograms per liter

J indicates an estimated value

R indicates data rejected and unusable

TICs indicates tentatively identified compounds

(1) indicates a matrix spike/matrix spike duplicate (MS/MSD) sample was collected with this sample.

RB indicates equipment rinsate blank

TABLE 2-20

SUMMARY OF TOTAL ORGANIC CARBON  
 DETECTED IN SURFACE SOIL SAMPLES  
 AND ASSOCIATED QUALITY CONTROL SAMPLES  
 SITE 13 - PUBLIC WORKS PCP DIP TANK AND WASH RACK  
 NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 MAY 13, 1993

SAMPLE LOCATION/NUMBER	13-SS-101	13-SS-102	13-SS-103	13-SS-106 (Duplicate 13-SS-103)	13-SS-104	13-SS-105
SAMPLE MATRIX UNITS	Soil mg/kg	Soil mg/kg	Soil mg/kg	Soil mg/kg	Soil mg/kg	Soil mg/kg
TOTAL ORGANIC CARBON:	51,700 J	14,200 J	21,200 J	55,700 J	7,060 J	15,100 J

## NOTES:

ND indicates compound was not detected

mg/kg indicates milligrams per kilogram

J indicates an estimated value

Equipment rinsate, field blank, and matrix spike/matrix spike duplicate shared with Site 11

TABLE 2-21

**SUMMARY OF VOLATILE ORGANIC COMPOUNDS  
DETECTED IN GROUNDWATER SAMPLES  
AND ASSOCIATED QUALITY CONTROL SAMPLES  
SITE 13 - PUBLIC WORKS PCP DIP TANK AND WASH RACK  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA  
JULY 29, 1993**

SAMPLE LOCATION/NUMBER	13GW03 <sup>(1)</sup>	13GW04	13GW05	13GW06	13GW07	13GW08	13GW09 (Duplicate 13-GW08)	13GWERB	13GWFB	13GWTB
SAMPLE MATRIX UNITS	Water ug/L	Water ug/L	Water ug/L	Water ug/L	Water ug/L	Water ug/L	Water ug/L	Water ug/L	Water ug/L	Water ug/L
<b>VOLATILE ORGANIC COMPOUNDS (VOCs):</b>										
Vinyl Chloride	4 J	ND	ND	200	ND	ND	ND	ND	ND	ND
Acetone	ND	ND	ND	ND	ND	ND	ND	ND	12	ND
Carbon Disulfide	ND	ND	ND	ND	ND	2 J	ND	ND	ND	ND
1,1-Dichloroethene	ND	ND	ND	7 J	ND	ND	ND	ND	ND	ND
1,2-Dichloroethene (total)	5 J	ND	ND	R	ND	ND	ND	ND	ND	ND
Chloroform	ND	ND	ND	ND	ND	ND	ND	3 J	ND	ND
Trichloroethene	2 J	5 J	1 J	R	1 J	ND	ND	ND	ND	ND
Tetrachloroethene	2 J	7 J	ND	R	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	55	ND	ND	ND	ND	ND	ND
Toluene	ND	ND	ND	ND	ND	2 J	2 J	ND	ND	ND
Chlorobenzene	3 J	110	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	15	ND	ND	6 J	5 J	ND	ND	ND
Xylene (total)	ND	ND	5 J	ND	ND	59	77	ND	ND	ND
<b>TOTAL VOCs:</b>	16 J	122 J	21 J	262 J	1 J	69 J	84 J	3 J	12	ND
<b>TOTAL TICs:</b>	ND	ND	19 J	ND	ND	42 J	70 J	ND	ND	ND

**NOTES:**

ND indicates compound was not detected

ug/L indicates micrograms per liter

J indicates an estimated value

R indicates data rejected and unusable

TICs indicates tentatively identified compounds

(1) indicates a matrix spike/matrix spike duplicate (MS/MSD) sample was collected with this sample.

ERB indicates equipment rinsate blank

FB indicates field blank

TB indicates trip blank

TABLE 2-22

**SUMMARY OF SEMI-VOLATILE ORGANIC COMPOUNDS  
 DETECTED IN GROUNDWATER SAMPLES  
 AND ASSOCIATED QUALITY CONTROL SAMPLES  
 SITE 13 - PUBLIC WORKS PCP DIP TANK AND WASH RACK  
 NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 JULY 29, 1993**

SAMPLE LOCATION/NUMBER	13GW03 <sub>(1)</sub>	13GW04	13GW05	13GW06	13GW07	13GW08	13GW09 (Duplicate 13GW08)	13GWERB	13GWFB
SAMPLE MATRIX UNITS	Water ug/L	Water ug/L	Water ug/L	Water ug/L	Water ug/L	Water ug/L	Water ug/L	Water ug/L	Water ug/L
<b>SEMI-VOLATILE ORGANIC COMPOUNDS (SVOCs):</b>									
1,4-Dichlorobenzene	1 J	ND	ND	ND	ND	ND	NA	ND	ND
1,2-Dichlorobenzene	ND	ND	ND	ND	ND	ND	NA	ND	ND
Naphthalene	ND	ND	3 J	ND	ND	96 J	NA	ND	ND
2-Methylnaphthalene	ND	ND	ND	ND	ND	170 J	NA	ND	ND
Acenaphthene	ND	ND	ND	1 J	ND	ND	NA	ND	ND
Dibenzofuran	ND	ND	ND	2 J	ND	ND	NA	ND	ND
Fluorene	ND	ND	ND	1 J	ND	ND	NA	ND	ND
Pentachlorophenol	32	ND	ND	20 J	ND	1,700	NA	ND	ND
<b>TOTAL SVOCs:</b>	33 J	ND	3 J	24 J	ND	1,966 J	NA	ND	ND
<b>TOTAL TICs:</b>	26 J	36 J	84 J	354 J	3 J	630 J	NA	5 J	18 J

**NOTES:**

ND indicates compound was not detected

NA indicates sample was not analyzed

ug/L indicates micrograms per liter

J indicates an estimated value

TICs indicates tentatively identified compounds

(1) indicates a matrix spike/matrix spike duplicate (MS/MSD) sample was collected with this sample.

ERB indicates equipment rinseate blank

FB indicates field blank

The RI/FS concluded that soils and groundwater are the affected media at the site. SVOCs were detected in surface soils, subsurface soils, and groundwater. PCP was detected in all media. One exceedance of vinyl chloride was detected in groundwater samples. As a result, the RI/FS recommended additional subsurface soil and groundwater sampling at the site, as well as additional hydrologic testing.



### 3.0 FIELD INVESTIGATION

The field investigation and sampling activities were conducted at Sites 12 and 13 from August 14, 1995 through September 27, 1995. Subsurface soil, groundwater, sediment, and surface water samples were collected for chemical analysis. Shelby tube samples also were collected from three boring locations at Site 12. These samples underwent grain size analysis and hydraulic conductivity testing.

In addition, aquifer testing was conducted at both sites. A pump test was conducted at Site 12 to identify the aquifer parameters and obtain transmissivity and specific conductivity data over the area of the site. Slug testing was conducted at both sites to define the aquifer parameters and obtain point values of transmissivity and specific conductivity.

Groundwater samples collected during Geoprobe® sampling were delivered via courier to Microbac Laboratories, Inc., of Newport News, Virginia for analysis. All other analytical samples were shipped via Federal Express to Quanterra Environmental Services, Inc., of Pittsburgh, Pennsylvania for analysis. Groundwater samples collected for anion analysis were shipped via Federal Express to Quanterra Environmental Services, Inc., of Knoxville, Tennessee.

All soil borings and monitoring well installations were performed by IMS Environmental of Norfolk, Virginia. Drilling equipment, including hollow stem augers, split-spoon samplers, and drill rods, was decontaminated with high pressure steam between each soil boring. Split-spoon samplers were decontaminated between samples by a detergent wash and rinse with potable water. The decontamination was performed to minimize the potential for cross-contamination. Decontamination fluids were collected in 55-gallon steel drums, labelled, and secured for proper disposal. The IDW will be managed based on the analytical results presented in Section 5.0.

The following sections provide the methodologies used to characterize each site at NAB Little Creek.

#### 3.1 Site 12 - Exchange Laundry Waste Disposal Area

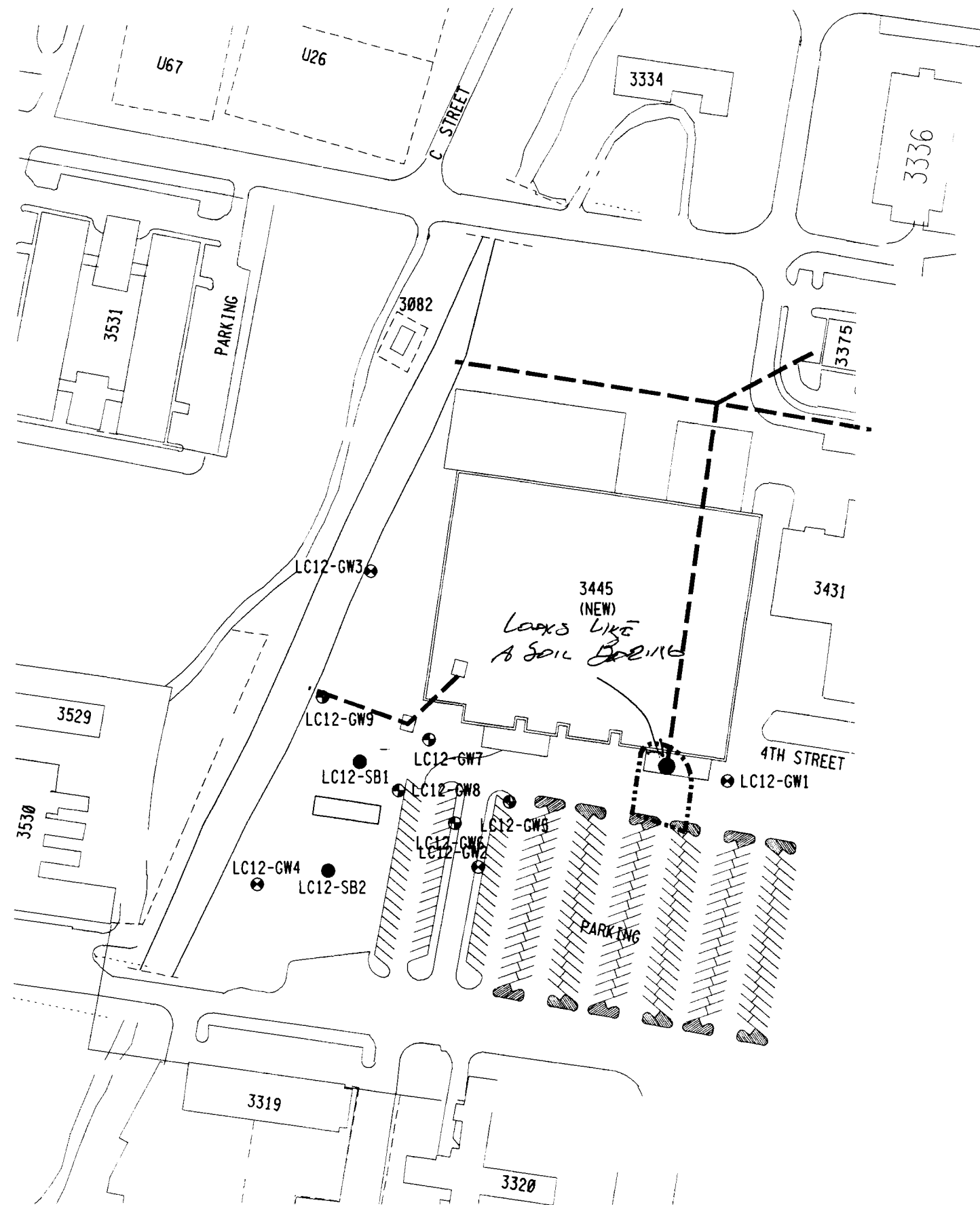
The Exchange Laundry/Dry Cleaning Facility was located in Building 3323 in the eastern portion of the installation. Field activities at this site included subsurface soil sampling, monitoring well installation, groundwater sampling, surface water and sediment sampling, aquifer testing (pump test and slug tests), and surveying. Table 3-1 provides a sampling summary for Site 12. Figure 3-1 presents a site map with sample locations for Site 12.

##### 3.1.1 Soil Boring Installation

Two soil borings were advanced at Site 12, at the locations provided on Figure 3-1. The borings were drilled using 4 1/2-inch inside diameter (ID) hollow-stem augers, and were advanced to depths ranging from 6 to 8 feet below ground surface. Soil cuttings generated during drilling activities were placed in 55-gallon steel drums, labelled, and stored on-site.

**TABLE 3-1**  
**SAMPLING SUMMARY**  
**SITE 12**  
**EXCHANGE LAUNDRY WASTE DISPOSAL AREA**  
**NAVAL AMPHIBIOUS BASE LITTLE CREEK**  
**VIRGINIA BEACH, VIRGINIA**  
**AUGUST - SEPTEMBER, 1995**

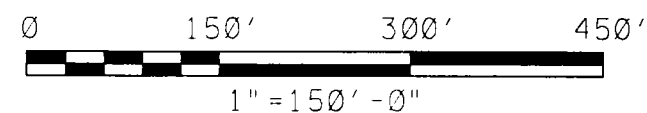
SITE 12		
SAMPLE NUMBER	CORRESPONDING SAMPLE LOCATION	ANALYSES CONDUCTED
<b>SOIL SAMPLES</b>		
12SB-107-02	LC12-GW5	Full TCL/TAL
12SB-107-03 (Dup. of -02)	LC12-GW5	Full TCL/TAL
12CL-101-20	LC12-GW5	TCL VOAs
12CL-101-21	LC12-GW5	TCL VOAs
12SB-108-02	LC12-GW6	Full TCL/TAL
12CL-102-20	LC12-GW6	TCL VOAs
12SB-109-02	LC12-GW7	Full TCL/TAL
12SB-110-02	LC12-GW8	Full TCL/TAL
12SB-111-02	LC12-GW9	Full TCL/TAL
12SB-101-00	LC12-SB01	TCL VOAs, CLP Metals
12SB-101-05 (Dup. of -00)	LC12-SB01	TCL VOAs, CLP Metals
12SB-101-02	LC12-SB01	TCL VOAs, CLP Metals
12SB-101-06	LC12-SB01	TCL VOAs, CLP Metals
12SB-102-00	LC12-SB02	TCL VOAs, CLP Metals
12SB-102-02	LC12-SB02	TCL VOAs, CLP Metals
12SB-102-04	LC12-SB02	TCL VOAs, CLP Metals
<b>GROUNDWATER SAMPLES</b>		
LC12-GW101	LC12-GW1	Full TCL/TAL, Anions
LC12-GW102	LC12-GW2	Full TCL/TAL, Anions
LC12-GW103	LC12-GW3	Full TCL/TAL, Anions
LC12-GW104	LC12-GW4	Full TCL/TAL, Anions
LC12-GW105	LC12-GW5	Full TCL/TAL, Anions
LC12-GW106	LC12-GW6	Full TCL/TAL, Anions
LC12-GW107	LC12-GW7	Full TCL/TAL, Anions
LC12-GW108	LC12-GW8	Full TCL/TAL, Anions
LC12-GW110 (Dup. of 108)	LC12-GW8	Full TCL/TAL, Anions
LC12-GW109	LC12-GW9	Full TCL/TAL, Anions
<b>SEDIMENT SAMPLES</b>		
LC12-SED-105	LC12-SED-105	CLP VOAs, Metals
LC12-SED-109 (Dup. of 105)	LC12-SED-105	CLP VOAs, Metals
LC12-SED-106	LC12-SED-106	CLP VOAs, Metals
LC12-SED-107	LC12-SED-107	CLP VOAs, Metals
LC12-SED-108	LC12-SED-108	CLP VOAs, Metals
<b>SURFACE WATER SAMPLES</b>		
LC12-SW-105	LC12-SW-105	CLP VOAs, Metals
LC12-SW-109 (Dup. of 105)	LC12-SW-105	CLP VOAs, Metals
LC12-SW-106	LC12-SW-106	CLP VOAs, Metals
LC12-SW-107	LC12-SW-107	CLP VOAs, Metals
LC12-SW-108	LC12-SW-108	CLP VOAs, Metals



## LEGEND

- FORMER WATER AND STORM SEWER LINE
- ..... SITE BOUNDARY
- SOIL BORING
- LC12-SB1 MONITORING WELL INSTALLED BY FWES
- ⊗ LC12-GW5 EXISTING MONITORING WELL INSTALLED BY FWES

## GRAPHIC SCALE



REV.	DATE	DESCRIPTION	APPR.
REVISIONS			
FIGURE 3-1			
SOIL BORING & MONITORING WELL SAMPLING LOCATIONS SITE 12 NAB - LITTLE CREEK VIRGINIA BEACH, VIRGINIA			
This Drawing is the property of the <b>FOSTER WHEELER ENVIRONMENTAL SERVICES</b> LIVINGSTON, NEW JERSEY AND IS LENT WITHOUT CONSIDERATION OTHER THAN THE BORROWER'S AGREEMENT THAT IT SHALL NOT BE RE- PRODUCED, COPIED, LENT, OR DISPOSED OF DIRECTLY OR INDIRECTLY NOR USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT IS SPECIFICALLY FURNISHED.			
DRAWN BY:	SAW	12/06/95	SCALE: 1" = 150' - 0"
CHECKED BY:			DRAWING No.
APPROVED BY:			0247-4-48-1202

Continuous split-spoon soil samples were obtained from each soil boring. Samples were collected using standard penetration tests following ASTM D 1586 Guidelines. This method was conducted using a 2-foot long, 2-inch ID split spoon sampler. Soil samples were visually classified by the on-site FWES geologist and descriptions were recorded on a Soil Boring Log. The soil classification is based on the Unified Soil Classification System (USCS). Other relevant information, such as evidence of contamination, moisture content, and blow counts, was recorded on the Soil Boring Log. Appendix A provides the Soil Boring Logs. **Table 3-2** contains a summary of soil boring details.

Three soil samples were collected from each boring and analyzed for TCL VOAs, TAL Metals, and Cyanide. Appendix B provides the chain-of-custody documentation for the subsurface soil samples. The split spoon samplers were decontaminated between each use. The soil samples and drill cuttings were screened in the field using a photoionization device (PID). The ambient air was monitored using the PID during drilling operations as a health and safety precaution. Each boring was abandoned using a cement/bentonite slurry following the completion of all sampling activities.

The purpose of the soil borings was to determine if the soil is a source for the VOC contamination and TAL Metals detected in the canal during the RI/FS. The sampling results are presented in Section 5.1.1.

### **3.1.2 Monitoring Well Installation**

Five soil borings were installed to the depth of the confining clay layer. Shelby tube samples of the confining clay layer were then collected from three of the soil borings to determine vertical hydraulic conductivity and for grain size analysis. Subsurface soil samples and samples of the confining clay layer also were collected for full TCL, and TCL VOC analysis, respectively. Continuous split-spoon soil samples were obtained using standard penetration tests following ASTM D 1586 Guidelines. This method was conducted using a 2-foot long, 2-inch ID split spoon sampler. Soil samples were visually classified by the on-site FWES geologist and descriptions were recorded on a Soil Boring Log. The soil classification is based on the USCS. Other relevant information, such as evidence of contamination, moisture content, and blow counts, was recorded on the Soil Boring Log. Appendix A provides the Soil Boring Logs for Site 12. Appendix B presents the chain-of-custody documentation for the subsurface soil samples. The split spoon samplers were decontaminated between each use. The soil samples and drill cuttings were screened in the field using a PID. The ambient air also was monitored using a PID during drilling operations as a health and safety procedure.

The data collected from the borings will be used in the determination of the confining-layer/aquifer boundary and the extent and rate of contaminant migration. The sampling results are presented in Section 5.1.1.

Five monitoring wells were then installed in the five borings. These wells were screened at a deeper interval than the existing wells. One of the wells installed was a 4-inch recovery well. The monitoring wells were constructed of 2-inch ID Schedule 40, flush-joint and threaded PVC casing, with a 20-foot long section of 0.010-inch slotted screen. The recovery well was constructed of 4-inch ID Schedule 40, flush-joint and threaded PVC casing, with a 15-foot long section of 0.010-inch slotted screen. A medium-grain sand pack extended from below the screen to a minimum of 1 foot above the top of the

TABLE 3-2

**MONITORING WELL AND SOIL BORING SPECIFICATIONS**  
**SITE 12**  
**EXCHANGE LAUNDRY WASTE DISPOSAL AREA**  
**NAVAL AMPHIBIOUS BASE - LITTLE CREEK**  
**VIRGINIA BEACH, VIRGINIA**  
**AUGUST, 1995**

MONITORING WELL NUMBER	TOTAL DEPTH (FT. BGS)	APPROXIMATE DEPTH TO WATER (FT. BGS)	SCREENED INTERVAL
LC12-GW5	22	7	2 - 20
LC12-GW6	22	7	7 - 22
LC12-GW7	26	7.5	4 - 24
LC12-GW8	24	7	2 - 22
LC12-GW9	24	7	2 - 22
12SB-01	8	7	NA
12SB-02	6	6	NA

**NOTES:**

FT indicates feet

BGS indicates below ground surface

NA indicates not applicable

screen. Bentonite pellets were placed above the sand pack and hydrated with potable water. A flush-mounted 12" cover and PVC locking cap were fitted at the top of four of the five new monitoring wells. Due to its location in a wooded area, monitoring well LC12-GW9 was constructed as a stick-up, consisting of approximately 3 ft. of protective steel locking casing and a 3-foot square concrete pad. **Table 3-2** contains a summary of monitoring well construction details. Appendix C provides a detailed description and diagram of the newly installed monitoring wells.

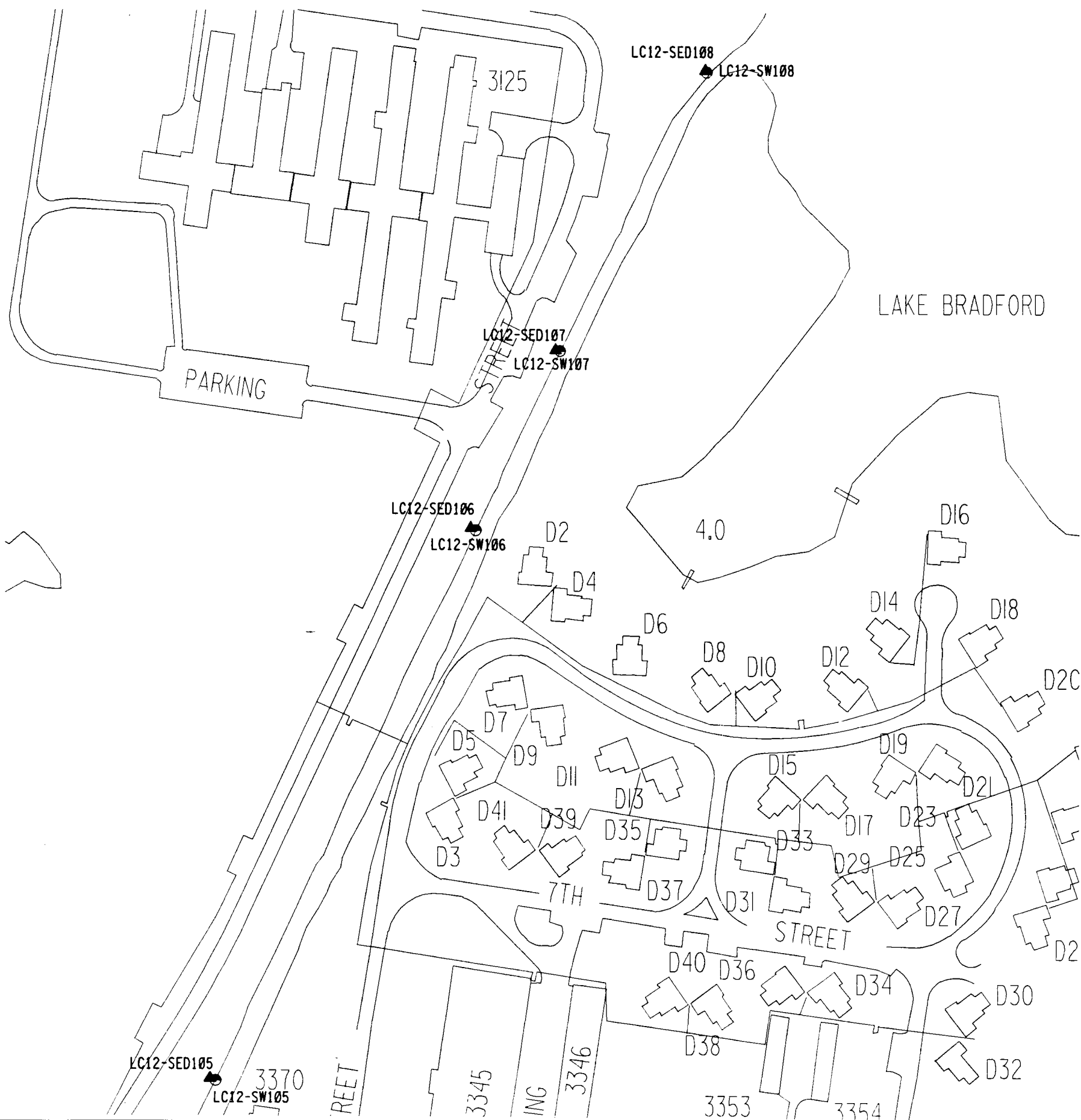
Following well construction activities, each monitoring well was developed, using a centrifugal pump, until the groundwater was essentially sediment-free. The wells were developed by pumping at a rate of approximately two gallons per minute. The water recovered was containerized in 55-gallon steel drums. The drums were stored in an area behind the car wash and were also used during the groundwater sampling. Subsequently, all drums containing purge water were secured for proper disposal.

### **3.1.3 Groundwater Samples**

Groundwater samples were collected from the nine monitoring wells at Site 12. Prior to sampling, a minimum of three well casing volumes was purged from each well by hand bailing. Purge water was containerized in 55-gallon steel drums and secured for proper disposal. Groundwater samples were collected from the wells using disposable polyethylene bottom loading bailers. The samples were transferred into laboratory prepared sample containers by pouring water from the bailer into the appropriate sample containers, slowly to minimize volatilization, and immediately stored on ice. One round of samples was collected from each well and the samples were analyzed for full TCL/TAL. The temperature, pH, and specific conductivity of the groundwater samples were measured in the field using a pH-temperature-conductivity meter and recorded in the field logbook. The sampling results are presented in Section 5.1.1. Appendix B provides the chain-of-custody documentation that accompanied the groundwater samples.

### **3.1.4 Surface Water and Sediment Samples**

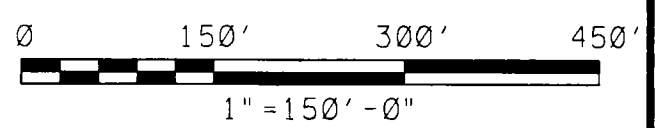
Four surface water and four sediment samples were collected upgradient of Site 12 (towards Lake Bradford) at intervals of approximately 120 feet. The sample locations are provided on **Figure 3-2**. The surface water samples were designated LC12-SW-105 through LC12-SW-108 and the sediment samples were designated LC12-SED-105 through LC12-SED-108. The surface water and sediment sampling was conducted sequentially. Sampling progressed from downstream locations to upstream locations, and the surface water sample was collected first. Sampling personnel were careful not to disturb the bottom sediment or create any unnecessary agitation at the sampling location. Both the surface water and sediment samples were collected near the shoreline, with the sediment sample being collected from the uppermost 6 inches of sediment using a decontaminated stainless steel spoon. The surface water and sediment samples were analyzed for TCL VOCs and TAL Metals. Appendix B provides the chain-of-custody documentation that accompanied the surface water and sediment samples. The results of this sampling are discussed in greater detail in Section 5.1.1.



### LEGEND

- FORMER WATER AND STORM SEWER LINE
- SITE BOUNDARY
- SURFACE WATER SAMPLE  
LC12-SW104
- ▲ SEDIMENT SAMPLE  
SED104

### GRAPHIC SCALE



REV.	DATE	DESCRIPTION	APPR.
REVISIONS			
FIGURE 3-2			
SEDIMENT/SURFACE WATER SAMPLING LOCATIONS SITE 12 NAB - LITTLE CREEK VIRGINIA BEACH, VIRGINIA			
This Drawing is the property of the <b>FOSTER WHEELER ENVIRONMENTAL SERVICES</b> LIVINGSTON, NEW JERSEY AND IS LENT WITHOUT CONSIDERATION OTHER THAN THE BORROWER'S AGREEMENT THAT IT SHALL NOT BE RE- PRODUCED, COPIED, LENT, OR DISPOSED OF DIRECTLY OR INDIRECTLY NOR USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT IS SPECIFICALLY FURNISHED.			
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CHECKED BY:			DRAWING No.
APPROVED BY:			0247-4-48-1203

CAD Rev No  
00 06-DEC-95

### **3.1.5 Aquifer Testing**

Slug tests were conducted in four monitoring wells to define the aquifer parameters and obtain point values of transmissivity and specific conductivity. Slug tests were performed in monitoring wells LC12-GW2, LC12-GW3, LC12-GW4, and LC12-GW8.

In addition to the slug tests, a constant rate pumping test was conducted on monitoring well LC12-GW6. Prior to conducting the pumping test, a preliminary step-test was conducted to determine the optimal pumping rate for the constant rate test. The step test was run at approximate pumping rates of 2 gallons per minute (gpm), 6.6 gpm, 8.4 gpm, 11.3 gpm, 11.9 gpm, and 12.15 gpm. A change in pumps was necessary to effectively stress the aquifer due to the available well yield, which was higher than initially estimated from drilling observations. The initial pump had a maximum discharge rate of 6.6 gpm.

Monitoring wells LC12-GW2, LC12-GW5, LC12-GW7, and LC12-GW8 were used as observation wells for the pumping test. These wells provide coverage on all four sides of the pumping well.

The pumping test was originally targeted for up to 72 hours. As a result of on-site time restrictions, and field analysis of the aquifer response to the test, FWES determined that a shorter pumping test would provide the information desired. In addition, four slug tests were conducted using one of the new deeper wells (monitoring well MW-8) and three of the existing shallow wells (monitoring wells MW-1, MW-2, and MW-3). FWES determined the data generated from the shortened pump test, combined with the slug test data, provided sufficient data to calculate aquifer yield, transmissivity, storativity, and hydraulic conductivity. These results are discussed in greater detail in Section 4.1.5.

### **3.1.6 Survey**

All new and existing groundwater monitoring wells and sample locations were surveyed by Patton Harris Rust & Associates of Virginia Beach, Virginia on September 27, 1995. Elevations of the top of PVC casing and concrete well pad were surveyed for each monitoring well.

## **3.2 Site 13 - Public Works PCP Dip Tank and Wash Rack**

The PCP Dip Tank and Wash Rack is located in the eastern portion of the installation. Field activities at this site included a Geoprobe® survey, soil boring installation, monitoring well installation, groundwater sampling, and surveying. **Table 3-3** provides a sampling summary for Site 13. **Figure 3-3** presents a site map with sample locations for Site 13.

### **3.2.1 Geoprobe® Samples**

A total of 10 groundwater samples were collected using the Geoprobe® method of sampling to characterize the nature and extent of a suspected groundwater plume in order to guide the placement of subsequent sampling locations. The Geoprobe® samples were collected at locations to the west and southwest of the former location of the PCP dip tank and wash rack. The Geoprobe® sampling was



**TABLE 3-3**

**SAMPLING SUMMARY**

**SITE 13**

**PUBLIC WORKS PCP DIP TANK AND WASH RACK**

**NAVAL AMPHIBIOUS BASE LITTLE CREEK**

**VIRGINIA BEACH, VIRGINIA**

**AUGUST - SEPTEMBER, 1995**

SITE 13		
SAMPLE NUMBER	CORRESPONDING SAMPLE LOCATION	ANALYSES CONDUCTED
<b>SOIL SAMPLES</b>		
13SB-101-02	LC13-SB01	Full TCL/TAL
13SB-102-02	LC13-SB02	Full TCL/TAL
13SB-103-02	LC13-SB03	Full TCL/TAL
13SB-104-02	LC13-SB04	TCL VOC/SVOC
13SB-104-03 (Dup. of -02)	LC13-SB04	TCL VOC/SVOC
13SB-105-02	LC13-SB05	TCL VOC/SVOC
13SB-106-02	LC13-SB06	TCL VOC/SVOC
13SB-107-02	LC13-SB07	TCL VOC/SVOC
13SB-108-02	LC13-SB08	TCL VOC/SVOC
13SB-109-02	LC13-GW9	TCL VOC/SVOC
13SB-110-02	LC13-GW10	TCL VOC/SVOC
13SB-110-03 (Dup. of -02)	LC13-GW10	TCL VOC/SVOC
13SB-111-02	LC13-GW11	TCL VOC/SVOC
13SB-112-02	LC13-GW12	TCL VOC/SVOC
13SB-113-02	LC13-GW13	TCL VOC/SVOC
<b>GROUNDWATER SAMPLES</b>		
LC13-GW102	LC13-GW2	TCL VOC/SVOC, Anions
LC13-GW103	LC13-GW3	TCL VOC/SVOC, Anions
LC13-GW104	LC13-GW4	TCL VOC/SVOC, Anions
LC13-GW105	LC13-GW5	TCL VOC/SVOC, Anions
LC13-GW106	LC13-GW6	TCL VOC/SVOC, Anions
LC13-GW107	LC13-GW7	TCL VOC/SVOC, Anions
LC13-GW108	LC13-GW8	TCL VOC/SVOC, Anions
LC13-GW114 (Dup. of 108)	LC13-GW8	TCL VOC/SVOC, Anions
LC13-GW109	LC13-GW9	Full TCL/TAL, Anions
LC13-GW110	LC13-GW10	Full TCL/TAL, Anions
LC13-GW115 (Dup. of 110)	LC13-GW10	Full TCL/TAL, Anions
LC13-GW111	LC13-GW11	Full TCL/TAL, Anions
LC13-GW112	LC13-GW12	TCL VOC/SVOC, Anions
LC13-GW113	LC13-GW13	TCL VOC/SVOC, Anions



STORAGE

STORAGE

7TH STREET

SITE 13

13SB-08

13SB-01

3174

3165E

13SB-04

13SB-03

3165B

13SB-02

13SB-06

13SB-05

13SB-07

3165D

O/W SEP.

CONCRETE  
WASH  
PAD AREA

LC13-GW13

LC13-GW9  
LC13-GW10

LC13-GW11

LC13-GW12

3165

3175

3293

3292

3655

## LEGEND



LOCATION OF FORMER  
PCP DIP TANK



SITE BOUNDARY



SOIL BORING LOCATION

13SB-01

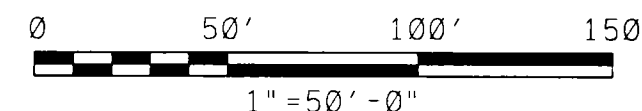


MONITORING WELL LOCATION

LC13-GW10

*Geoprobe locations*

## GRAPHIC SCALE



REV.	DATE	DESCRIPTION	APPR.
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### REVISIONS

FIGURE 3-3

SOIL BORING & MONITORING WELL  
SAMPLING LOCATIONS

SITE 13

NAB - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA



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performed by IMS Environmental, of Norfolk, Virginia. A van-mounted hydraulic solid metal probe was driven into the ground to a depth of 12 feet below ground surface (bgs). At a depth of 12 feet, the probe was opened and groundwater pumped out. Groundwater was anticipated at approximately 7 feet below ground surface, thus allowing a sufficient area of the aquifer to be bridged for sample collection. The samples were transferred from the sampling probe, through teflon tubing, into laboratory prepared sample containers. This was done slowly to minimize volatilization. The samples were immediately stored on ice and transported to Microbac Laboratories, Inc., of Newport News, Virginia. Each sample was analyzed for TCL VOCs. Appendix B provides the chain-of-custody documentation that accompanied the groundwater samples. The sampling results are discussed in greater detail in Section 5.1.2. Appendix D provides the complete results of the Geoprobe® sampling.

### 3.2.2 Soil Boring Installation

Eight shallow soil borings were advanced at Site 13 from the source area of PCP (dip tank and drying rack area). These locations are provided on **Figure 3-3**. The borings were drilled using 4 1/2-inch inside diameter (ID) hollow-stem augers, and were advanced to a depth of 4 feet below ground surface. Soil cuttings generated during drilling activities were placed in 55-gallon steel drums, labelled, and stored on-site.

Continuous split-spoon soil samples were obtained from each soil boring. Samples were collected using standard penetration tests following ASTM D 1586 Guidelines. This method was conducted using a 2-foot long, 2-inch ID split spoon sampler. Soil samples were visually classified by the on-site FWES geologist and descriptions were recorded on a Soil Boring Log. The soil classification is based on the USCS. Other relevant information, such as evidence of contamination, moisture content, and blow counts, was recorded on the Soil Boring Log. Appendix A provides the Soil Boring Logs.

One soil sample was collected from each boring. Samples collected from three of the soil borings (soil borings 13SB-101, -102, and -103) were analyzed for full TCL/ TAL. Samples collected from the remaining soil borings were analyzed for TCL VOCs and SVOCs. Appendix B provides the chain-of-custody documentation for the subsurface soil samples. The split spoon samplers were decontaminated between each use. The soil samples and drill cuttings were screened in the field using a photoionization device (PID). The ambient air was monitored using the PID during drilling operations as a health and safety precaution. Each boring was abandoned using a cement/bentonite slurry following the completion of all sampling activities.

The purpose of the soil borings is to identify/determine if the subsurface soil is acting as the source of the PCP and vinyl chloride plumes as detected in previous investigations by sampling and analyzing subsurface soil samples. The sampling results are discussed in greater detail in Section 5.1.2.

### 3.2.3 Monitoring Well Installation

Five monitoring wells were installed at Site 13 to monitor the suspected groundwater plume and determine the extent of constituents which may impact human health and/or the environment by sampling and analyzing subsurface soil and shallow groundwater.

The locations of these monitoring wells were determined based on the results of the Geoprobe® survey and the results of previous sampling investigations. The five monitoring wells were installed to the south/southwest of the former PCP tank. Continuous split-spoon soil samples were obtained using standard penetration tests following ASTM D 1586 Guidelines. This method was conducted using a 2-foot long, 2-inch ID split spoon sampler. Soil samples were visually classified by the on-site FWES geologist and descriptions were recorded on a Soil Boring Log. The soil classification is based on the USCS. Other relevant information, such as evidence of contamination, moisture content, and blow counts, was recorded on the Soil Boring Log. Appendix A provides the Soil Boring Logs for Site 13.

One soil sample was collected from each boring and analyzed for TCL VOCs and SVOCs. The soil sample was collected from the split spoon sampler. Appendix B presents the chain-of-custody documentation for the subsurface soil samples. The split spoon samplers were decontaminated between each use. The soil samples and drill cuttings were screened in the field using a PID. The ambient air also was monitored using a PID during drilling operations as a health and safety procedure.

Four of the five monitoring wells were constructed of 2-inch ID Schedule 40, flush-joint and threaded PVC casing, with a 10-foot long section of 0.010-inch slotted screen. Monitoring well LC13-GW10 was constructed of 2-inch ID Schedule 40, flush-joint and threaded PVC casing, with a 15-foot long section of 0.010-inch slotted screen. A medium-grain sand pack extended from below the screen to a minimum of 1 foot above the top of the screen. Bentonite pellets were placed above the sand pack and hydrated with potable water. A flush-mounted 12" cover and a PVC locking cap were fitted at the top of each monitoring well. **Table 3-4** contains a summary of monitoring well construction details. Appendix C provides a detailed description and diagram of the newly installed monitoring wells.

Following well construction activities, each monitoring well was developed, using a centrifugal pump, until the groundwater was essentially sediment-free. The wells were developed by pumping at a rate of approximately two gallons per minute. The water recovered was containerized in 55-gallon steel drums. The drums were stored at the monitoring well for use during the groundwater sampling. Subsequently, all drums containing purge water were secured for proper disposal.

### **3.2.4 Groundwater Samples**

Groundwater samples were collected from seven of the eight pre-existing monitoring wells and from all five newly installed monitoring wells at Site 13. Prior to sampling, a minimum of three well casing volumes was purged from each well by hand bailing. Purge water was containerized in 55-gallon steel drums and secured for proper disposal. Groundwater samples were collected from the wells using disposable teflon bottom loading bailers. The samples were transferred into laboratory prepared sample containers by pouring water from the bailer into the appropriate sample containers, slowly to minimize volatilization, and immediately stored on ice. One round of samples was collected from each well and the samples were analyzed for TCL VOCs and TCL SVOCs. The temperature, pH, and specific conductivity of the groundwater samples were measured in the field using a pH-temperature-conductivity meter and recorded in the field logbook. Appendix B provides the chain-of-custody documentation that accompanied the groundwater samples.

**TABLE 3-4**  
**MONITORING WELL SPECIFICATIONS**  
**SITE 13**  
**PUBLIC WORKS PCP DIP TANK AND WASH RACK**  
**NAVAL AMPHIBIOUS BASE - LITTLE CREEK**  
**VIRGINIA BEACH, VIRGINIA**  
**AUGUST, 1995**

MONITORING WELL NUMBER	TOTAL DEPTH (FT. BGS)	APPROXIMATE DEPTH TO WATER (FT. BGS)	SCREENED INTERVAL
LC13-GW9	12	5	2 - 12
LC13-GW10	16	4.5	2 - 17
LC13-GW11	12	5	2 - 12
LC13-GW12	12	4	2 - 12
LC13-GW13	12	5	2 - 12

**NOTES:**

FT indicates feet

BGS indicates below ground surface

NA indicates not applicable

### **3.2.5 Aquifer Testing**

Slug tests were conducted in four monitoring wells to define the aquifer parameters and obtain point values of transmissivity and specific conductivity. Slug tests were performed in monitoring wells LC13-GW6, LC13-GW7, LC13-GW11, and LC13-GW12. These results are discussed in greater detail in Section 4.2.5.

### **3.2.6 Survey**

All new and existing groundwater monitoring wells and soil boring locations were surveyed by Patton Harris Rust & Associates of Virginia Beach, Virginia. Elevations of the top of casing and concrete well pad were surveyed for each monitoring well.

## 4.0 PHYSICAL CHARACTERISTICS

Physical data obtained during the field program have been used to characterize each site under investigation. Results from the field program are presented below by site. In addition, data from the previous investigations are utilized whenever applicable to supplement the findings obtained during this investigation.

### 4.1 Site 12 - Exchange Laundry Waste Disposal Area

Results of the physical characterization for Site 12 are presented below. Previous investigations of the site consist of IAS ('84), RVS ('86), IRI ('91), site characterizations ('92), and RI/FS ('93). Data from these studies are utilized whenever applicable.

#### 4.1.1 Site Topography, Drainage, and Surface Features

Site 12 encompasses the area immediately surrounding a former storm drain catch basin previously used for disposal of laundering-related materials (i.e., soaps, sizing, sludges, etc.). Site 12 also includes the area where sampling was conducted. The entire site is approximately 11 acres in size. Site 12 is located in a heavily used commercial area. The site is bordered to the east by what was previously B Street. The former B Street has been included in the new parking area for the Base Commissary. The site is bordered to the south by 3rd Street, to the west by a drainage canal, and to the north by 5th Street. The maximum length of the site is approximately 960 feet, and the average width is approximately 515 feet. The location of Site 12 is presented on **Figure 1-2**. The majority of the site is related to the Commissary, which was recently constructed and completed in May 1993.

The Commissary building covers approximately 20 percent of the site. A car wash and a waste water transfer station are located in the southwest corner of the site. Paved parking areas cover a large portion of the remaining surface area of Site 12. Grass covered areas lie between the Commissary and parking lots, and between the Commissary and the wooded area along the drainage canal.

The site is relatively level with an average elevation of approximately 11.5 feet above msl. The lowest elevations surveyed on the site occur along the western boundary where previous sediment samples were collected in the drainage canal. Sediment samples collected during this phase were collected from a length of canal located to the north of Site 12, between the site and Lake Bradford. The sediment samples were obtained during low tide. These locations are presented on **Figure 3-2**.

Surface water drainage on the site is controlled by a network of storm sewers, with the outflow being directed into the drainage canal. Water in the drainage canal is shallow (less than 1 foot in depth) and appeared stagnant, or very slow moving to the north at all times of observation.



#### 4.1.2 Geology

Drilling activities permitted observation of the thickness and extent of undisturbed natural material and depth to water. A geologic log was prepared for each monitoring well boring drilled during this investigation and is presented in Appendix A.

The top 4 to 6 inches of each boring consists of top soil and organic materials such as grass and root matter. A clay layer approximately four feet thick is found immediately below top soil in borings LC12-GW1, LC12-GW3, and LC12-GW9. This clay layer is not present in the other borings at the site. The clay layer was found immediately below the top soil at soil borings 12SB-01 and 12SB-02 at a thickness of five to six feet thick. At the five monitoring well locations, a mixed sand/clay layer was found to a depth of four to five feet immediately below the top soil. Below this layer, a layer of fine to medium sand was observed at all monitoring well locations. The sand layer is fairly homogeneous, with traces of silts, thin clay lenses (approximately 6 inches thick or less), and small gravel. This layer ranged in depth from 21 feet bgs in borings LC12-GW5, LC12-GW6, and LC12-GW9 to 24 feet bgs in boring LC12-GW7. Below the sand layer is a solid grey clay. This clay was encountered at all five monitoring well locations, and is of undetermined thickness.

##### 4.1.2.1 Shelby Tube Sample Analysis

Three shelly tube samples were collected from the underlying clay layer, located approximately 20 to 24 feet bgs. The shelly tube samples were collected from the first two foot interval in the clay layer. Shelly tubes are undisturbed samples, and were obtained to ascertain the physical properties of the clay layer. The undisturbed samples were shipped via Federal Express to Quanterra Environmental Services, of Pittsburgh, Pennsylvania. The samples were analyzed by Geotechnics of East Pittsburgh, Pennsylvania for Hydrometer/Grain size by ASTM D 422, Atterberg Limits Tests by ASTM D 4318, Specific Gravity of Soils Test by ASTM D 854, and Constant Head Permeability Tests by ASTM D 854. Shelly tube samples were collected from the borings associated with monitoring wells LC12-GW7, LC12-GW8, and LC12-GW9.

Sample 12ST-101-24, collected from the boring for monitoring well LC12-GW7, consists of a brown silty sand (non-plastic fines). Under the USCS, the sample is classified as SM: silty SANDS/SAND-silt mixtures. Sieve analysis showed the sample consists of 76.8 percent sand and 23.2 percent silt and clay. The specific gravity and the coefficient of permeability of the sample were not available due to a void that had developed in the sample during shipping.

Sample 12ST-102-22, collected from the boring for monitoring well LC12-GW8, consists of a brown, poorly graded sand. The sample is classified under USCS as SP: poorly graded SANDS with little or no fines. Sieve analysis showed the sample consists of 95.5 percent sand and 4.5 percent silt and clay. The specific gravity of the sample is 2.70 and the coefficient of permeability is  $2.3 \times 10^{-4}$  cm/sec (0.66 ft/day).

Sample 12ST-103-22, collected from the boring for monitoring well LC12-GW9, consists of a grey silty, clayey sand. The sample is classified under USCS as SC-SM: silty SAND to clayey SAND. Sieve



analysis showed the sample consists of 73.1 percent sand and 26.9 percent silt and clay. The specific gravity of the sample is 2.70 and the coefficient of permeability is  $2.5 \times 10^{-6}$  cm/sec (0.1 ft/day). Other testing provided a liquid limit of 22, a plastic limit of 16, and a plasticity index of 6.

Appendix E provides the results of the analysis of the physical properties of the Shelby tube samples.

#### **4.1.3 Stratigraphy**

Geologic data are presented on two geologic cross-sections. **Figure 4-1** presents the locations of the two cross sections, and the cross sections themselves are presented on **Figure 4-2** and **Figure 4-3**. Geologic logs from the monitoring wells installed during this investigation, as well as those generated during the 1993 RI/FS, were used in the subsurface interpretation. These logs were made from continuous split spoon sampling and geologic contacts were interpolated from this information. From the literature, undisturbed natural soil and sediment underlying the site can be classified as that of the Columbia Formation.

#### **4.1.4 Groundwater Level Data**

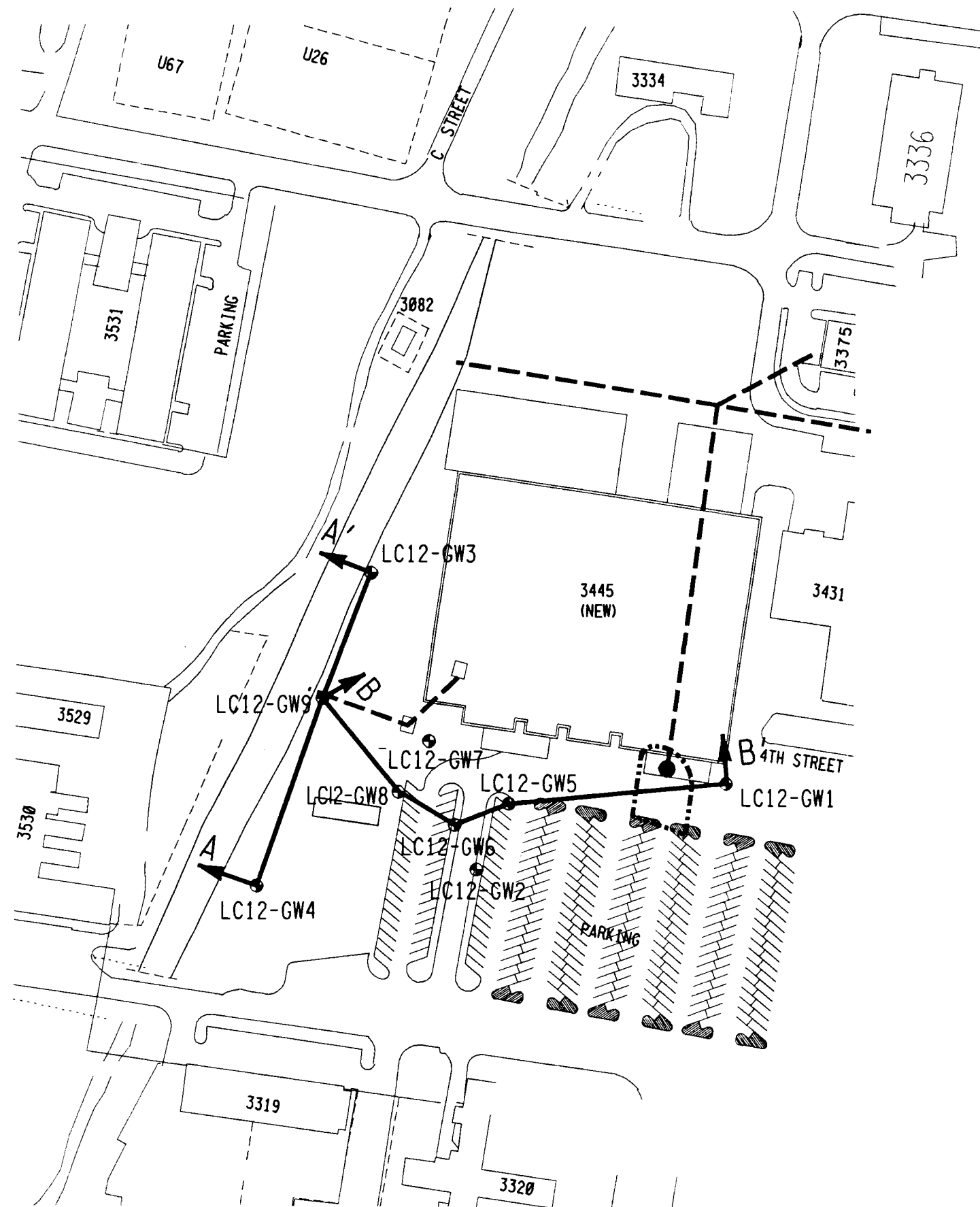
Groundwater beneath the site is located in the undisturbed natural soils and sediment. Monitoring wells were installed within the sand layer to investigate hydrologic conditions, including:

- Depth to groundwater,
- Groundwater flow patterns, and
- Groundwater hydraulic gradients.

Depth to water was measured in all nine monitoring wells at Site 12. Depth to water and water elevation data are summarized in **Table 4-1**. All data is from monitoring wells screening the shallow water table aquifer. Groundwater levels were measured on September 21, 1995 in all nine monitoring wells.

On September 21, 1995, groundwater elevations ranged from 4.29 feet above msl in monitoring well LC12-GW8 to 4.85 feet above msl in monitoring well LC12-GW1. The groundwater contours for the water table aquifer are presented on **Figure 4-4**. Groundwater flow is to the south/southwest, in the general direction of the drainage canal. Previous investigations have concluded that groundwater flow is to the west, also towards the drainage canal. The average hydraulic gradient calculated for the site from the September 21, 1995 water level data is  $1.2 \times 10^{-3}$  ft/ft. The RI/FS provided a hydraulic gradient for the site of  $8.69 \times 10^{-4}$  ft/ft. The IRI investigation provided a hydraulic gradient of  $1.6 \times 10^{-3}$  ft/ft. The monitoring wells used during that study were destroyed during the construction of the Base Commissary.

A number of factors may have contributed to the apparent change in groundwater flow direction noted during the investigation, as well as the differences in the average hydraulic gradient. The differences may be attributed to the installation of additional monitoring wells during the past two studies, and differences in local climatological conditions. The acquisition of data from additional monitoring wells would provide a greater insight into the actual groundwater flow direction and hydraulic gradient at the

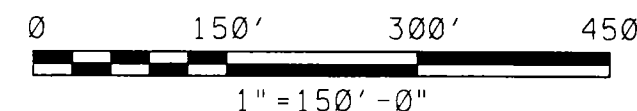


## LEGEND

- FORMER WATER AND STORM SEWER LINE
- ..... SITE BOUNDARY
- LC12-GW5 MONITORING WELL LOCATION

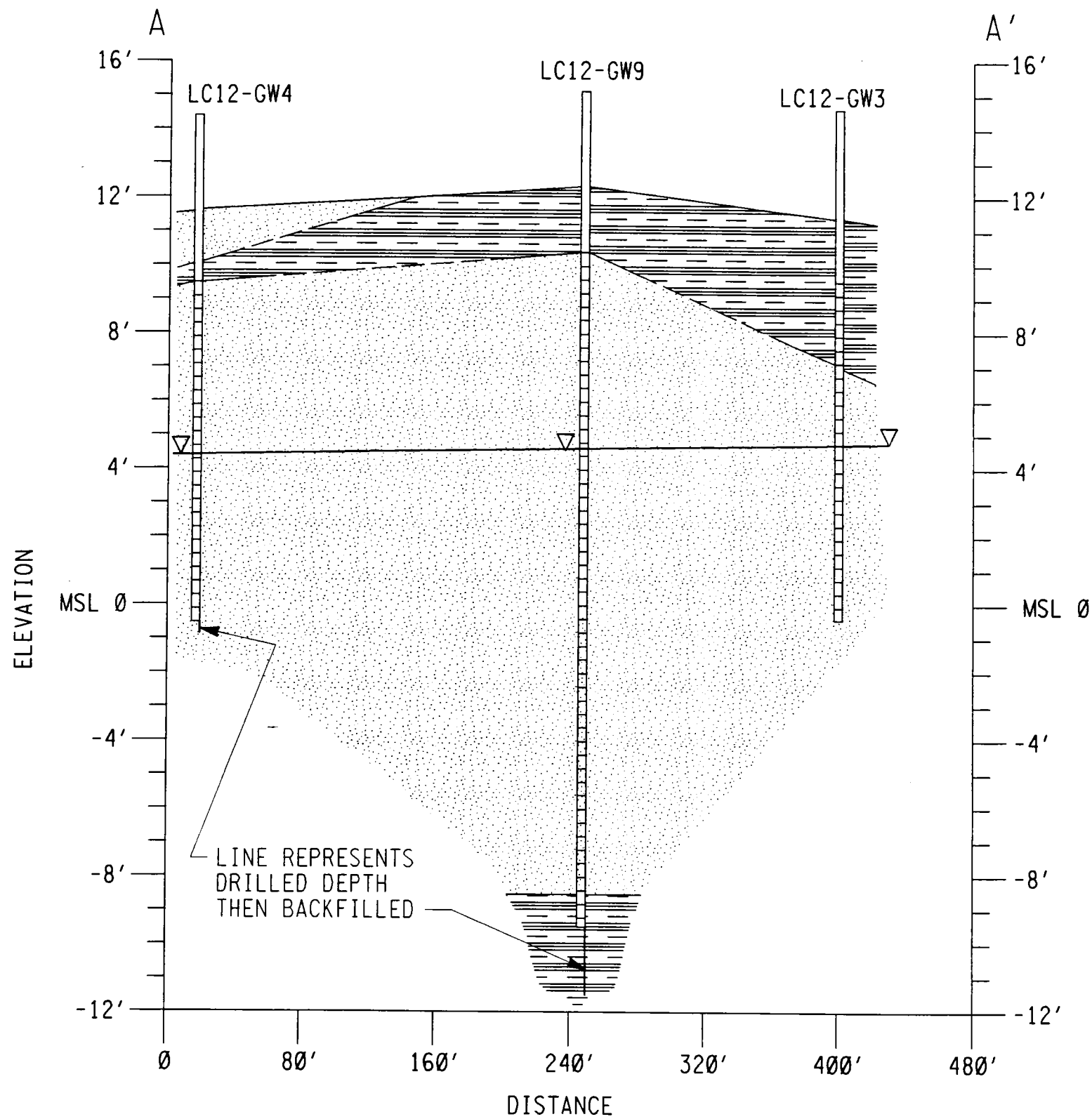
↑ B    B' ↑ GEOLOGICAL CROSS SECTION

## GRAPHIC SCALE

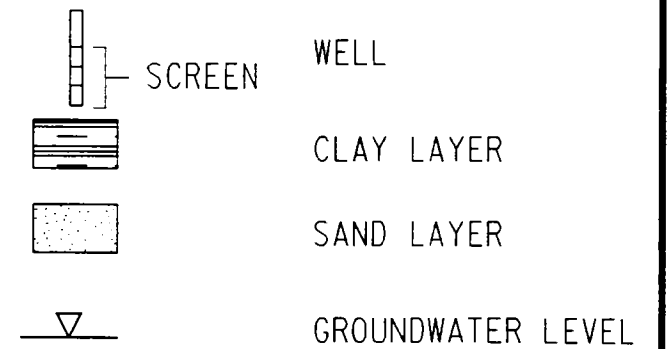


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FIGURE 4-1			
PLAN OF GEOLOGICAL CROSS SECTION SITE 12 NAB - LITTLE CREEK VIRGINIA BEACH, VIRGINIA			
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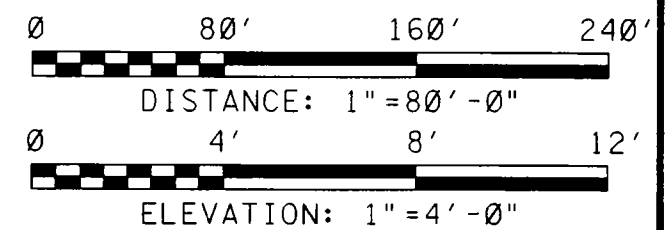
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# LEGEND



# GRAPHIC SCALE



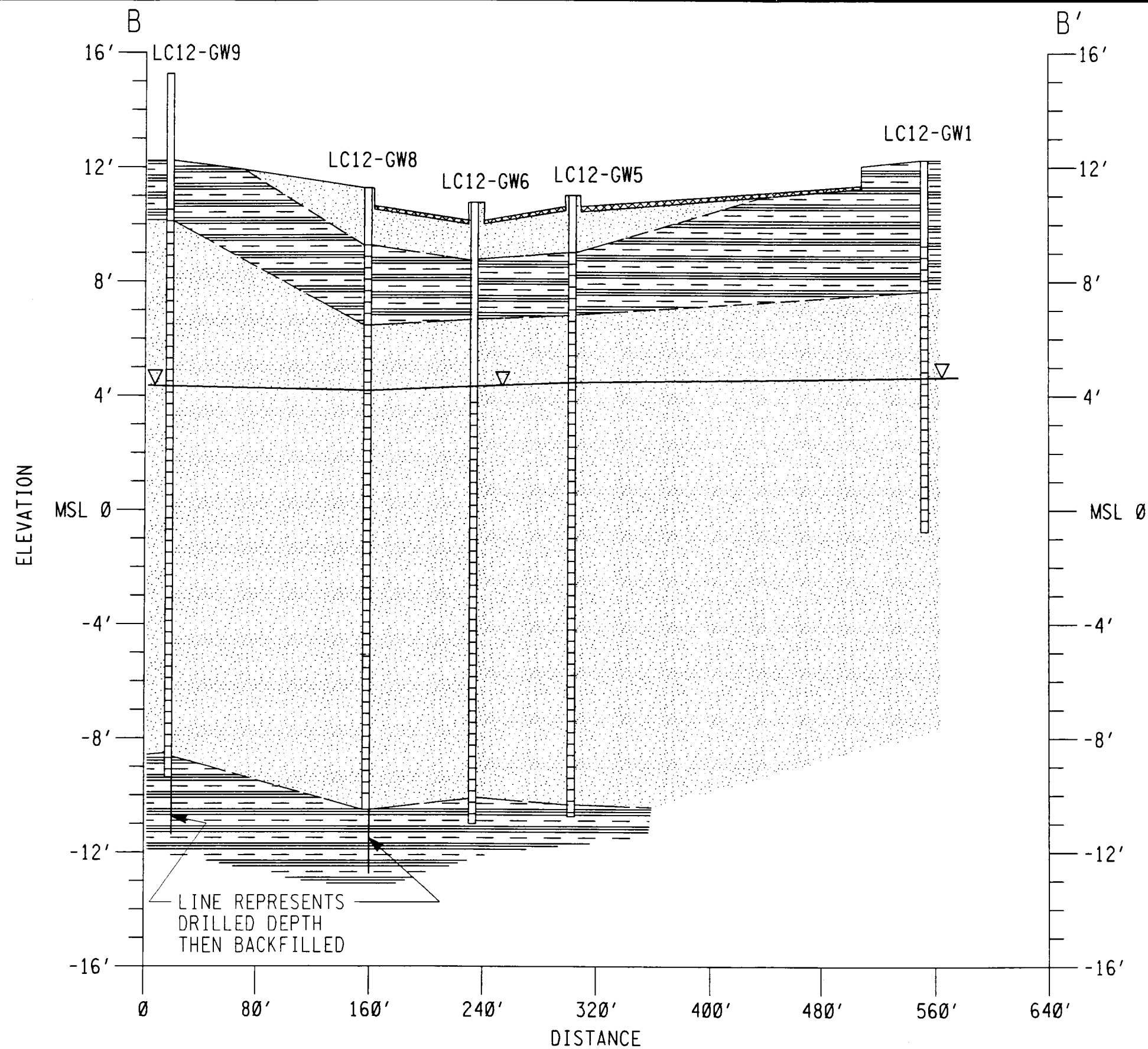
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FIGURE 4-2			
GEOLOGICAL CROSS SECTION			
SECTION A-A'			
SITE 12			
NAB - LITTLE CREEK			
VIRGINIA BEACH, VIRGINIA			
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GEOLOGICAL CROSS SECTION  
(LOOKING WEST)

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**GEOLOGICAL CROSS SECTION**  
(LOOKING NORTH)

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FIGURE 4-3			
GEOLOGICAL CROSS SECTION			
SECTION B-B'			
SITE 12			
NAB - LITTLE CREEK			
VIRGINIA BEACH, VIRGINIA			
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**TABLE 4-1**

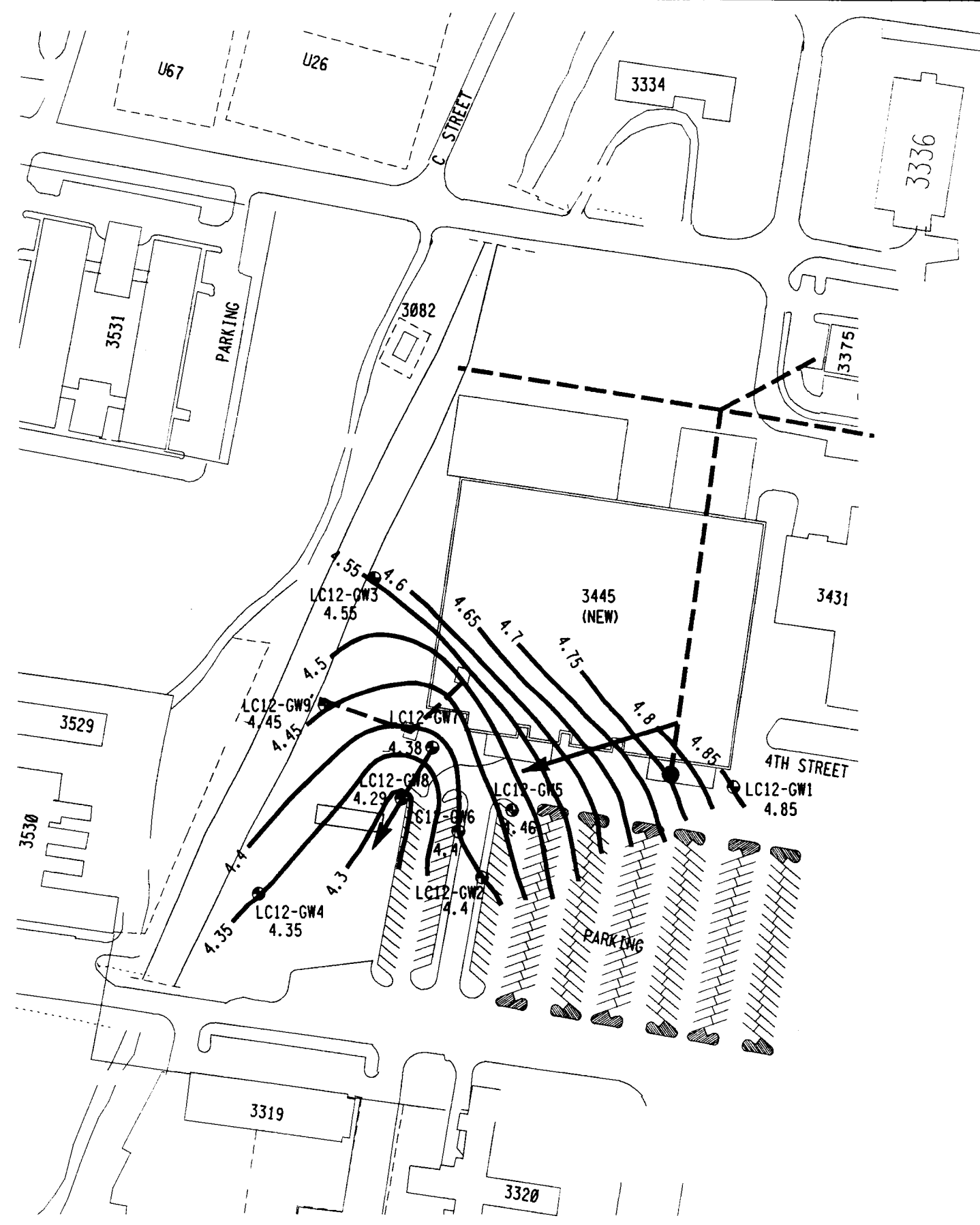
**GROUNDWATER ELEVATIONS ABOVE MEAN SEA LEVEL  
SITE 12  
EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA  
SEPTEMBER 21, 1995**

<b>MONITORING WELL NUMBER</b>	<b>MEASURING POINT ABOVE MSL (FT)</b>	<b>DEPTH TO WATER (FT)</b>	<b>WATER LEVEL ABOVE MSL (FT)</b>
<b>LC12-GW1</b>	12.14	7.29	4.85
<b>LC12-GW2</b>	10.89	6.49	4.40
<b>LC12-GW3</b>	14.62	10.07	4.55
<b>LC12-GW4</b>	14.40	10.05	4.35
<b>LC12-GW5</b>	11.14	6.68	4.46
<b>LC12-GW6</b>	10.82	6.42	4.40
<b>LC12-GW7</b>	11.17	6.79	4.38
<b>LC12-GW8</b>	11.27	6.98	4.29
<b>LC12-GW9</b>	15.16	10.71	4.45

**NOTES:**

MSL indicates Mean Sea Level

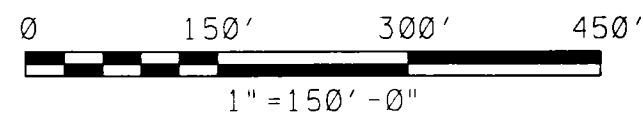
FT indicates feet



## LEGEND

- FORMER WATER AND STORM SEWER LINE
- MONITORING WELL LOCATION WITH GROUNDWATER ELEVATION ABOVE MSL
- GROUNDWATER CONTOUR @ 0.05 FT. INTERVAL
- DIRECTION OF FLOW

## GRAPHIC SCALE



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### REVISIONS

FIGURE 4-4

GROUNDWATER CONTOUR MAP  
SEPTEMBER 21, 1995  
SITE 12  
NAB - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA



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site. Local climatological conditions (i.e. drought, heavy rain) may temporarily change both flow direction and hydraulic gradient. Also, recent utilities excavation was conducted in the area of the car wash (between the commissary and the drainage canal). These subsurface activities also may have influenced the groundwater table, shifting the flow direction to the south/southwest.

Extended periods of rain or drought are known to influence groundwater levels, especially that of the water table aquifer. Because only one round of water levels were collected at this site, no comparisons can be made using local climatological data. Site 12 is located within approximately one mile of Chesapeake Bay. During the RI/FS, a tidal survey and long-term groundwater table monitoring was conducted. As a result, the RI/FS determined that only a slight tidal influence would be expected in the monitoring wells at this location.

#### **4.1.5 Aquifer Testing**

The following section discusses the results of the slug tests and pumping test conducted at Site 12.

##### **Slug Testing**

The estimates of hydraulic conductivity (K) were prepared with the data generated from the slug tests, and using the Bouwer-Rice method (Bouwer, H., 1976). The AQTESOLV™ program (Geraghty and Miller, 1989) was utilized to calculate and present the data collected in the field. The tests indicated the horizontal hydraulic conductivities of the sediments were  $1.9 \times 10^{-4}$  ft/sec,  $1.9 \times 10^{-4}$  ft/sec,  $3.5 \times 10^{-4}$  ft/sec, and  $3.6 \times 10^{-4}$  ft/min for LC12-GW2, LC12-GW3, LC12-GW4, and LC12-GW8, respectively. An average hydraulic conductivity of  $2.7 \times 10^{-4}$  ft/sec was calculated for the site. Appendix F provides the AQTESOLV™ program output.

The groundwater flow velocity has been calculated by the following method:

$$V = Ki/n_e$$

where: V = velocity in ft/day

K = hydraulic conductivity in ft/sec

i = groundwater gradient in feet/foot

$n_e$  = effective porosity in percent as represented by a decimal

The hydraulic conductivity has been estimated from the slug test data to be  $2.7 \times 10^{-4}$  ft/sec. The gradient is estimated to be  $1.2 \times 10^{-3}$  ft/ft. The effective porosity has been estimated based on the soil boring logs to be 0.3 (Todd, 1980). Thus, the groundwater flow velocity is estimated to be 0.093 ft/day.

##### **Pumping Test**

The results of the step test indicated the aquifer underlying Site 12 is very productive. Based on the drawdown observed in the test well, LC12-GW6, the maximum pumping rate of the pump used for the test was less than the potential aquifer yield. A discharge rate of 12 gpm was selected for the constant rate pumping test.

The pumping test was started at 11:30 am at a discharge rate of 12 gpm. Water levels were monitored in each observation well and the pumping well. After determining elapsed time and corresponding drawdown in each well, the water level data were plotted in the field on semilog paper to permit field analysis of the pumping test.

Although all four observation wells, LC12-GW2, LC12-GW5, LC12-GW7, and LC12-GW8, exhibited minor aquifer drawdowns in response to pumping in well LC12-GW6, the semilog plots of drawdown versus time demonstrate clear trends sufficient for analysis. Test data from each observation well was analyzed using the modified non-leaky artesian formula developed by Cooper and Jacob in 1946 (Selected Analytical Methods for Well and Aquifer Evaluation, Walton 1962). This method also is known as the straight line method of aquifer analysis.

Aquifer transmissivity beneath Site 12 ranged from approximately 23,000 gallons per day per foot (gpd/ft) in observation well LC12-GW2 to 35,000 gpd/ft in observation well LC12-GW7. The transmissivity average for the four observation wells equaled approximately 28,000 gpd/ft. A check on the straight line segment ( $T_{st}$ ) used to calculate each observation well transmissivity indicates each transmissivity value is valid. Pumping test results are presented in **Table 4-2**. Transmissivity calculated for pumping well LC12-GW6 ranged from 14,000 to 40,000 gpd/ft.

Aquifer storativity ranged from approximately  $1.3 \times 10^{-3}$  in observation well LC12-GW5 to  $8.8 \times 10^{-3}$  in observation well LC12-GW8. The storativity average for the four observation wells equaled approximately  $3.3 \times 10^{-3}$ . Appendix F presents the data generated during the pump test.

Results of the pumping test indicate the aquifer underlying Site 12 is very transmissive. Although the results are based on a testing time of only 6.5 hours, the preliminary results indicate a pump and treat system would effectively operate if selected as a remedial option for the site. An extended pumping test prior to a final pump and treat system design would be required. An extended test would be used to determine water table dewatering effects on extended pumping periods and optimal long term pumping rates to maximize contaminant capture without excess water withdrawal.

## **4.2 Site 13 - Public Works PCP Dip Tank And Wash Rack**

Results of the physical characterization for Site 13 are presented below.

### **4.2.1 Site Topography, Drainage, and Surface Features**

Site 13 is located in an area with numerous buildings which house utility and maintenance departments for the base. The majority of the area surrounding the site is covered by either asphalt or buildings. There are buildings located east and south of the site; west of the site is another secure storage area surrounded by chain link fence; and north of the site is 7<sup>th</sup> Street. Just south of 7<sup>th</sup> Street is a narrow strip of lawn area.



**TABLE 4-2**  
**PUMPING TEST RESULTS**  
**SITE 12**  
**EXCHANGE LAUNDRY WASTE DISPOSAL AREA**  
**NAVAL AMPHIBIOUS BASE - LITTLE CREEK**  
**VIRGINIA BEACH, VIRGINIA**  
**SEPTEMBER 25, 1995**

PARAMETER UNITS		TRANSMISSIVITY (gpd/ft)	STORATIVITY (Dimensionless)	Tsl (minutes)	To (minutes)	Delta S (feet)
Pumping Well	GW-6	14,400				0.22
		39,600				0.08
Observation Wells	GW-2	22,630	1.530E-03	29.6	10.5	0.14
	GW-5	28,035	1.300E-03	27.9	9.9	0.113
	GW-7	35,200	1.460E-03	56.2	20	0.09
	GW-8	27,550	8.820E-03	242	8.6	0.115
Observation well average		28,354	3.278E-03	89	12	0.115

**NOTES:**

- 1) Tsl equals time that must pass before straight line segment becomes valid for Jacob straight line interpretation
- 2) To equals zero drawdown intercept time
- 3) Delta S equals drawdown over one full log cycle

Site 13 covers approximately 8,500 square feet based on a length of 170 feet and an average width of 50 feet, as shown on **Figure 2-2**. Nearly all of the north half of the site is located in an asphalt covered secure storage area surrounded by chain link fence. The south half of the site is a gravel parking area or weeded area.

The site is relatively level with an average elevation of approximately 7.5 feet above msl. The lowest ground elevations occur east of the site along 7<sup>th</sup> Street at monitoring well LC13-GW2.

#### **4.2.2 Geology**

Five monitoring wells were installed during this investigation. The geology is based on boring logs of these five wells and on previous work at the site. Monitoring wells installed during the RVS ('86) are LC13-GW1 through LC13-GW5, monitoring wells installed during the RI/FS are LC13-GW6 through LC13-GW8, and monitoring wells installed during this investigation are LC13-GW9 through LC13-GW13. Geologic logs were prepared for each soil and monitoring well boring drilled during this investigation and are presented in Appendix A.

The majority of the site is paved or gravel covered. Below the initial layer of asphalt and/or gravel is a thin, one foot thick layer of sand. This clay layer was observed at the majority of monitoring well locations and ranged in thickness from 2 feet at monitoring well LC13-GW12 to 8 feet at monitoring well LC13-GW8. Sand is then encountered at all boring locations at Site 13. Monitoring well LC13-GW1, installed during a previous study, encountered a second clay layer at a depth of approximately 19 feet bgs.

#### **4.2.3 Stratigraphy**

Geologic data are presented on two geologic cross-sections. **Figure 4-5** presents the locations of the two cross sections, and the cross sections themselves are presented on **Figure 4-6** and **Figure 4-7**. Geologic logs from existing monitoring wells also were used in the subsurface interpretation. Geologic logs for the existing wells were developed from split spoon samples collected at varying intervals versus the continuous split spoon sampling used in this investigation. As such, geologic contacts were primarily interpolated from data collected during this investigation. General site stratigraphy consists of sand, clay or clay with sand, sand, and then clay.

#### **4.2.4 Groundwater Level Data**

Groundwater beneath the site is located in the soils and sediment. During water sampling performed as part of this study, water level data was recorded for the monitoring wells at the site. During this investigation the following were established:

- Depth to groundwater,
- Groundwater flow patterns, and
- Groundwater hydraulic gradients.



STORAGE

STORAGE

LC13-GW1

A

LC13-GW2

3653

7TH STREET

LC13-GW5

3174

LC13-GW8

3165E

3165B

3165D

3175

SITE 13

LC13-GW3

O/W SEP.

CONCRETE  
WASH  
PAD AREA

B

3293

3292

3655

LC13-GW7

LC13-GW13

LC13-GW6

LC13-GW4

LC13-GW10

LC13-GW9

LC13-GW11

LC13-GW12

A'

3165

## LEGEND



LOCATION OF FORMER  
PCP DIP TANK

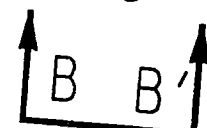


SITE BOUNDARY

LC13-GW10

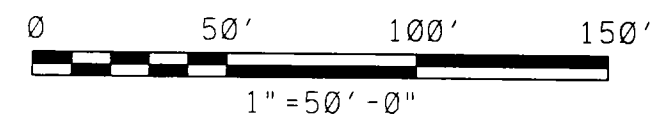


MONITORING WELL LOCATION



GEOLOGICAL CROSS SECTION

## GRAPHIC SCALE



REV.	DATE	DESCRIPTION	APPR.
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### REVISIONS

FIGURE 4-5

PLAN OF GEOLOGICAL  
CROSS SECTIONS

SITE 13

NAB - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA



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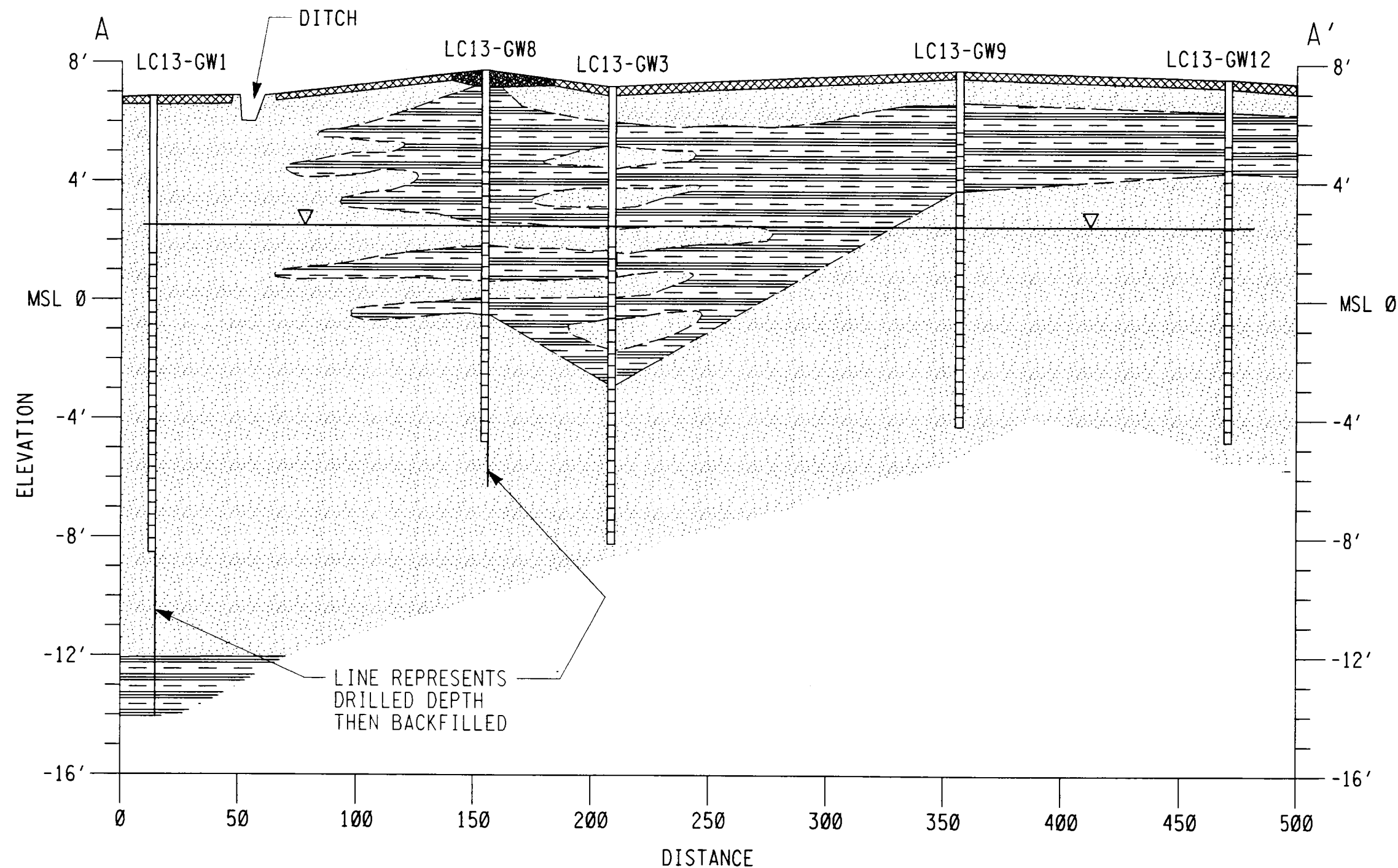
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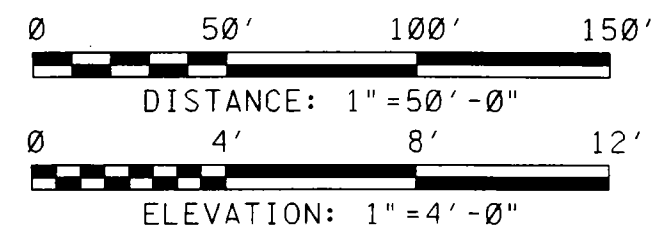
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# LEGEND

- SCREEN WELL
- CLAY LAYER
- SAND LAYER
- GRAVEL LAYER
- PAVEMENT LAYER
- GROUNDWATER LEVEL

# GRAPHIC SCALE



## GEOLOGICAL CROSS SECTION (LOOKING EAST)

REV.	DATE	DESCRIPTION	APPR.
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### REVISIONS

FIGURE 4-6  
GEOLOGICAL CROSS SECTION  
SECTION A-A'  
SITE 13  
NAB - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA

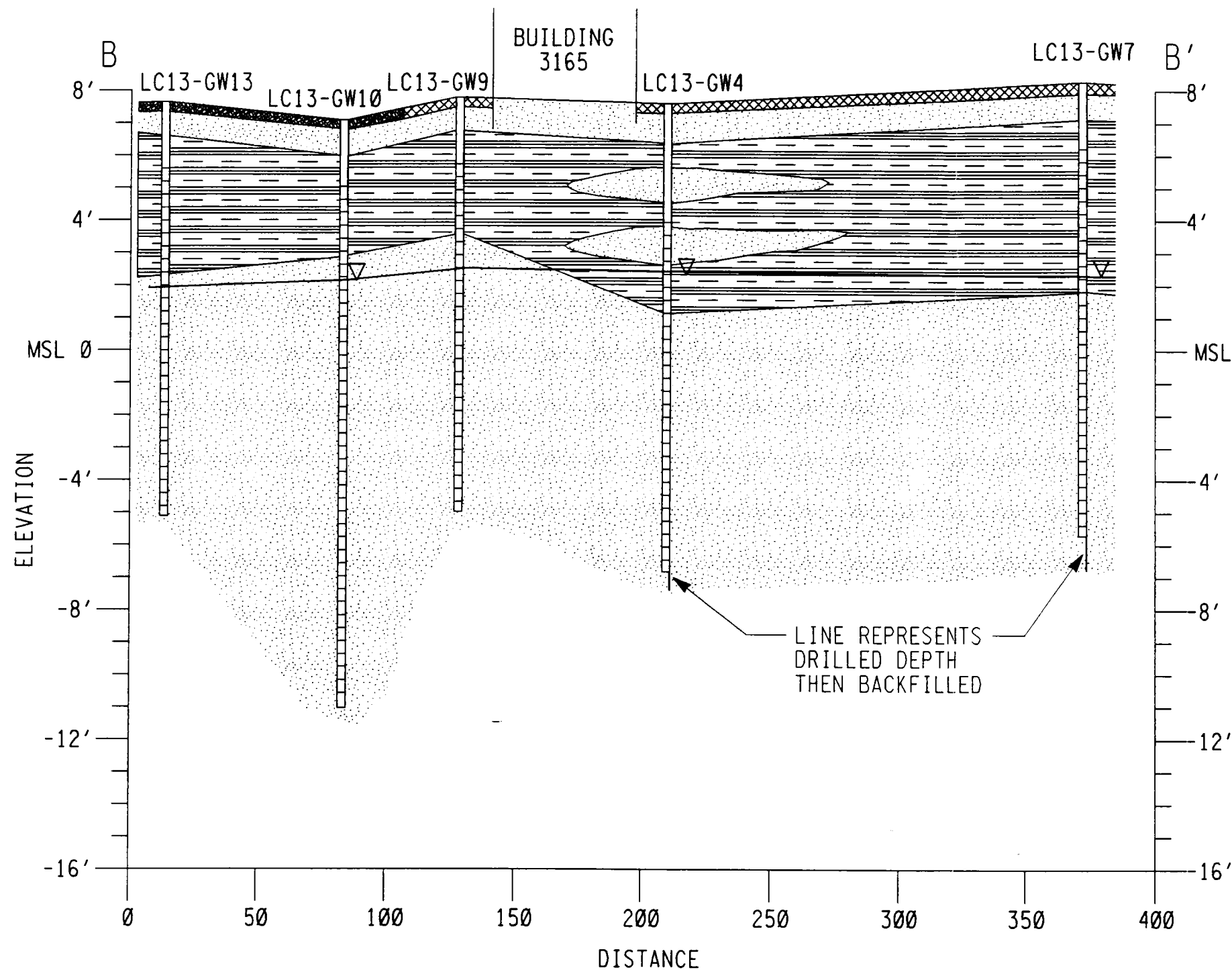


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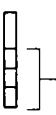





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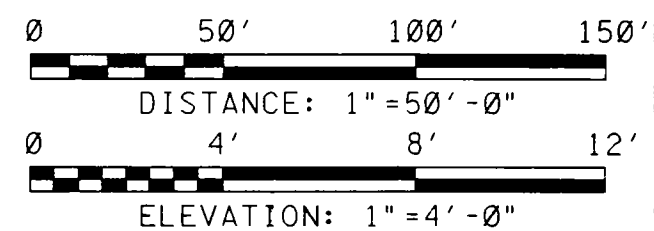
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# LEGEND

-  WELL
-  CLAY LAYER
-  SAND LAYER
-  GRAVEL LAYER
-  PAVEMENT LAYER
-  GROUNDWATER LEVEL

# GRAPHIC SCALE



## GEOLOGICAL CROSS SECTION (LOOKING NORTH)

REV.	DATE	DESCRIPTION	APPR.
REVISIONS			
FIGURE 4-7			
GEOLOGICAL CROSS SECTION SECTION B-B'			
SITE 13			
NAB - LITTLE CREEK VIRGINIA BEACH, VIRGINIA			
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Depth to water was measured in all thirteen monitoring wells at Site 13. Depth to water and water elevation data are summarized in **Table 4-3**. All data is from monitoring wells screening the shallow water table aquifer. Groundwater levels were measured on September 21, 1995.

On September 21, 1995, groundwater elevations ranged from 2.34 feet above msl in monitoring well LC13-GW11 to 2.65 feet above msl in monitoring well LC13-GW1. The groundwater contours for the water table aquifer are presented on **Figure 4-8**. Groundwater flow is relatively flat, with a slight trend towards the southwest. Previous investigations have similarly concluded groundwater flow is to the west/southwest. The average hydraulic gradient calculated for the site from the September 21, 1995 water level data is  $1.46 \times 10^{-3}$  ft/ft. The RI/FS provided a hydraulic gradient for the site of  $4.7 \times 10^{-4}$  ft/ft.

Extended periods of rain or drought are known to influence groundwater levels, especially that of the water table aquifer. Because only one round of water levels were collected at this site, no comparisons can be made using local climatological data. Site 13 is located within approximately one mile of Chesapeake Bay. From previous work on the base, only a slight tidal influence would be expected in the monitoring wells at this location.

#### **4.2.5 Aquifer Testing**

The estimates of hydraulic conductivity (K) were prepared with the data generated from the slug tests, and using the Bouwer-Rice method (Bouwer, H., 1976). The AQTESOLV™ program (Geraghty and Miller, 1989) was utilized to calculate and present the data collected in the field. The tests indicated the horizontal hydraulic conductivities of the sediments were  $2.9 \times 10^{-4}$  ft/sec,  $4.8 \times 10^{-4}$  ft/sec,  $2.7 \times 10^{-4}$  ft/sec, and  $1.6 \times 10^{-4}$  ft/sec for LC13-GW6, LC13-GW7, LC13-GW11, and LC13-GW12, respectively. An average hydraulic conductivity of  $3.0 \times 10^{-4}$  ft/sec was calculated for the site. Appendix F provides the AQTESOLV™ program output.

The groundwater flow velocity has been calculated by the following method:

$$V = Ki/n_e$$

where: V = velocity in ft/day

K = hydraulic conductivity in ft/sec

i = groundwater gradient in feet/foot

$n_e$  = effective porosity in percent as represented by a decimal

The hydraulic conductivity has been estimated from the slug test data to be  $3.0 \times 10^{-4}$  ft/sec. The gradient is estimated to be  $1.46 \times 10^{-3}$  ft/ft. The effective porosity has been estimated based on the soil boring logs to be 0.3 (Todd, 1980). Thus, the groundwater flow velocity is estimated to be 0.13 ft/day.

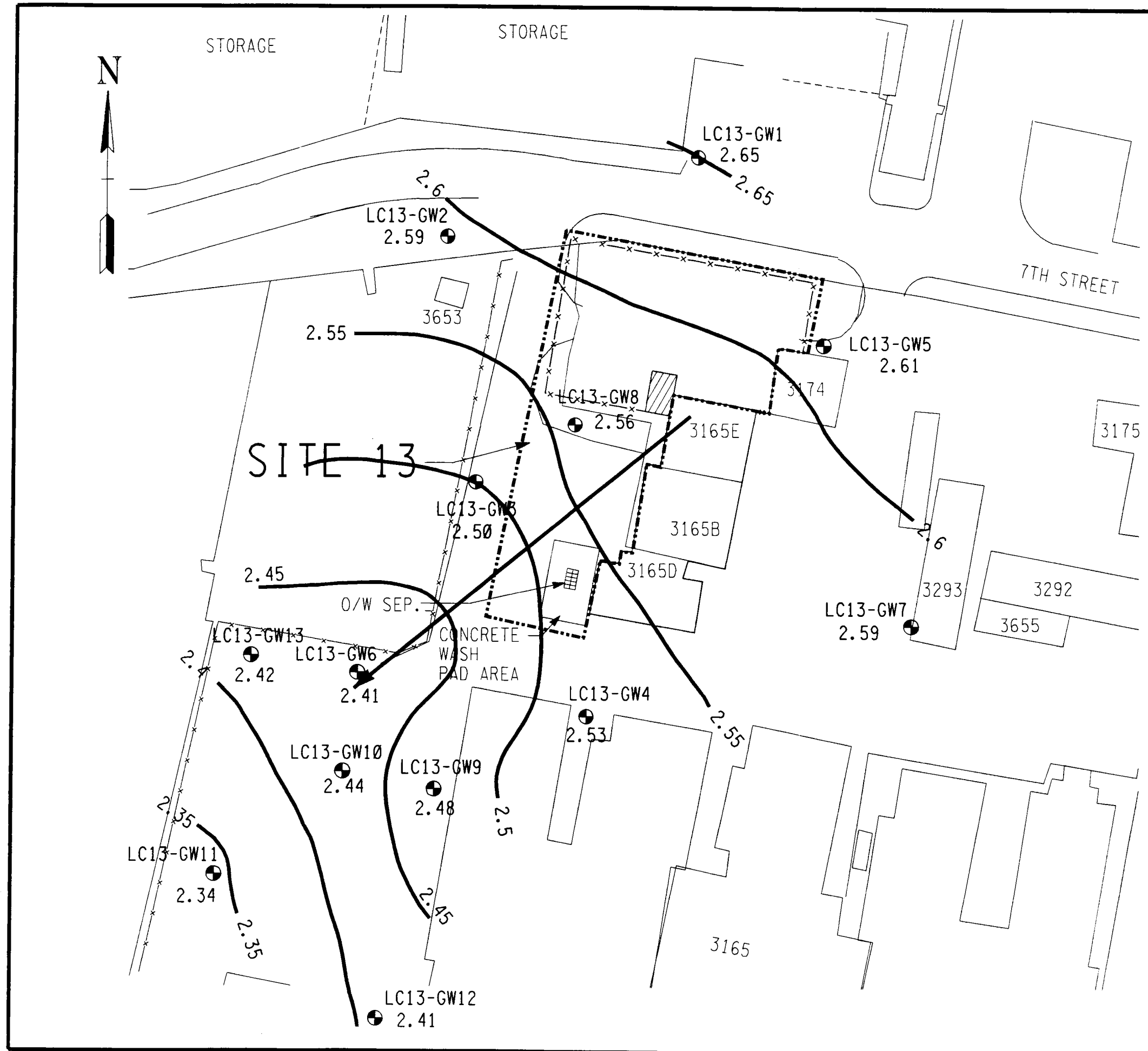
**TABLE 4-3**  
**GROUNDWATER ELEVATIONS ABOVE MEAN SEA LEVEL**  
**SITE 13**  
**PUBLIC WORKS PCP DIP TANK AND WASH RACK**  
**NAVAL AMPHIBIOUS BASE - LITTLE CREEK**  
**VIRGINIA BEACH, VIRGINIA**  
**SEPTEMBER 21, 1995**

<b>MONITORING WELL NUMBER</b>	<b>MEASURING POINT ABOVE MSL (FT)</b>	<b>DEPTH TO WATER (FT)</b>	<b>WATER LEVEL ABOVE MSL (FT)</b>
LC13-GW1	6.85	4.20	2.65
LC13-GW2	5.89	3.30	2.59
LC13-GW3	7.16	4.66	2.50
LC13-GW4	7.56	5.03	2.53
LC13-GW5	7.14	4.53	2.61
LC13-GW6	7.37	4.96	2.41
LC13-GW7	8.05	5.46	2.59
LC13-GW8	7.67	5.11	2.56
LC13-GW9	7.71	5.23	2.48
LC13-GW10	7.25	4.81	2.44
LC13-GW11	7.53	5.19	2.34
LC13-GW12	7.44	5.03	2.41
LC13-GW13	7.78	5.36	2.42

**NOTES:**

MSL indicates Mean Sea Level

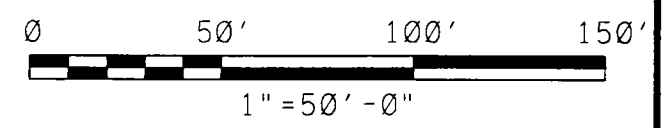
FT indicates feet



# LEGEND

- LOCATION OF FORMER PCP DIP TANK
- SITE BOUNDARY
- LC13-GW10 MONITORING WELL LOCATION WITH GROUNDWATER ELEVATION ABOVE MSL
- GROUNDWATER CONTOUR @ 0.05 INTERVAL
- DIRECTION OF FLOW

## GRAPHIC SCALE



REV.	DATE	DESCRIPTION	APPR.
REVISIONS			
FIGURE 4-8			
GROUNDWATER CONTOUR MAP			
SEPTEMBER 21, 1995			
SITE 13			
NAB - LITTLE CREEK			
VIRGINIA BEACH, VIRGINIA			
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## 5.0 NATURE AND EXTENT OF CONSTITUENTS OF CONCERN

Soil and water samples were collected from each site at Little Creek to characterize the natural chemical composition of these sites and constituents of concern. The samples were analyzed by Quanterra Environmental Services, Inc., of Pittsburgh, Pennsylvania and the results were validated by Heartland Environmental Services of St. Peters, Missouri. The data evaluation and quality assurance was conducted by FWES and is presented in Section 5.2. The Data Validation Report is included in Appendix G.

The discussion of the chemical findings has been divided in the following manner for each site: subsurface soil, groundwater, and surface water and sediment. In this way, the data is presented in the manner in which it is often found in the environment, from remaining source area through potential pathways.

Subsurface soil data represents source areas and often provides an indication of any remaining constituents of concern that still exist. Subsurface sampling often provides data on worst case conditions. Groundwater data identifies those constituents which have dissolved into the saturated zone and may migrate with groundwater flow from the area of concern. Surface water and sediment data often represent the potential ingestion pathway through the food chain and bioaccumulation. In addition, surface water data often indicates releases of constituents of concern into the environment, and sediment data often represents their accumulation.

Organic data will be presented in three groupings: volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and pesticides and polychlorinated biphenyls (PCBs). The TAL parameters represent inorganic constituents of concern, including 23 metals and cyanide. A summary of the characteristics, concentrations, and horizontal extent of the impact to various media is presented in this section.

### 5.1 Summary of Analytical Results

#### 5.1.1 Site 12 - Exchange Laundry Waste Disposal Area

##### Subsurface Soils

Eleven subsurface soil samples were collected at varying depths from soil borings at Site 12. In addition, three clay samples also were collected from the confining clay layer. The soil and clay samples were analyzed for VOCs, SVOCs, pesticides and PCBs, and TAL metals.

##### **VOCs**

Three VOCs, acetone, tetrachloroethene, and toluene, were detected in several of the soil samples. **Table 5-1** contains a summary of VOCs detected in subsurface soil and clay samples, and associated quality control samples, at Site 12. Acetone, a common laboratory contaminant, was detected in 12CL-101-20 and 12SB-110-02 at 5 µg/kg (J) and 7 µg/kg (J), respectively. Tetrachloroethene was detected in 12SB-101-00 and 12SB-101-02 at 16 µg/kg and 2 µg/kg (J), respectively. Toluene was detected in 12SB-101-

TABLE 5-1

VOLATILE ORGANIC COMPOUNDS DETECTED IN SOIL SAMPLES  
 SITE 12  
 EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 AUGUST, 1995

SAMPLE NUMBER MATRIX UNITS	12CL-101-20 SOIL UG/KG	12CL-101-21 SOIL UG/KG	12CL-102-20 SOIL UG/KG	12SB-101-00 SOIL UG/KG	12SB-101-02 SOIL UG/KG	12SB-101-05 SOIL UG/KG	12SB-101-06 SOIL UG/KG
Methyl chloride	12 U	11 U	11 U	12 U	11 U	11 U	10 U
Methyl bromide	12 U	11 U	11 U	12 U	11 U	11 U	10 U
Vinyl Chloride	12 U	11 U	11 U	12 U	11 U	11 U	10 U
Chloroethane	12 U	11 U	11 U	12 U	11 U	11 U	10 U
Methylene chloride	12 U	11 U	11 U	12 U	11 U	11 U	10 U
Acetone	5 J	11 U	11 U	61 U	55 U	31 U	33 U
Carbon disulfide	12 U	11 U	11 U	12 U	11 U	11 U	10 U
1,1-Dichloroethene	12 U	11 U	11 U	12 U	11 U	11 U	10 U
1,1-Dichloroethane	12 U	11 U	11 U	12 U	11 U	11 U	10 U
1,2-dichloroethene (Total)	12 U	11 U	11 U	12 U	11 U	11 U	10 U
Chloroform	12 U	11 U	11 U	12 U	11 U	11 U	10 U
1,2-Dichloroethane	12 U	11 U	11 U	12 U	11 U	11 U	10 U
Methyl ethyl ketone	12 U	11 U	11 U	12 U	11 U	11 U	10 U
1,1,1-Trichloroethane	12 U	11 U	11 U	12 U	11 U	11 U	10 U
Carbon tetrachloride	12 U	11 U	11 U	12 U	11 U	11 U	10 U
Bromodichloromethane	12 U	11 U	11 U	12 U	11 U	11 U	10 U
1,2-Dichloropropane	12 U	11 U	11 U	12 U	11 U	11 U	10 U
cis-1,3-Dichloropropene	12 U	11 U	11 U	12 U	11 U	11 U	10 U
Trichloroethene	12 U	11 U	11 U	12 U	11 U	11 U	10 U
Dibromochloromethane	12 U	11 U	11 U	12 U	11 U	11 U	10 U
1,1,2-Trichloroethane	12 U	11 U	11 U	12 U	11 U	11 U	10 U
Benzene	12 U	11 U	11 U	12 U	11 U	11 U	10 U
trans-1,3-Dichloropropene	12 U	11 U	11 U	12 U	11 U	11 U	10 U
Bromoform	12 U	11 U	11 U	12 U	11 U	11 U	10 U
4-Methyl-2-Pentanone	12 U	11 U	11 U	12 U	11 U	11 U	10 U
2-Hexanone	12 U	11 U	11 U	12 U	11 U	11 U	10 U
Tetrachloroethene	12 U	11 U	11 U	16	2 J	11 U	10 U
1,1,2,2-Tetrachloroethane	12 U	11 U	11 U	12 U	11 U	11 U	10 U
Toluene	12 U	11 U	11 U	1 J	11 U	4 J	10 U
Chlorobenzene	12 U	11 U	11 U	12 U	11 U	11 U	10 U
Ethylbenzene	12 U	11 U	11 U	12 U	11 U	11 U	10 U
Styrene	12 U	11 U	11 U	12 U	11 U	11 U	10 U
Xylene (total)	12 U	11 U	11 U	12 U	11 U	11 U	10 U

## NOTES:

UG/KG indicates micrograms per kilogram

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

TABLE 5-1 (CONTINUED)

VOLATILE ORGANIC COMPOUNDS DETECTED IN SOIL SAMPLES  
 SITE 12  
 EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 AUGUST, 1995

SAMPLE NUMBER MATRIX UNITS	12SB-102-00 SOIL UG/KG	12SB-102-02 SOIL UG/KG	12SB-102-04 SOIL UG/KG	12SB-107-02 SOIL UG/KG	12SB-107-03 SOIL UG/KG	12SB-08-02 SOIL UG/KG	12SB-109-02 SOIL UG/KG	12SB-110-02 SOIL UG/KG
Methyl chloride	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
Methyl bromide	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
Vinyl Chloride	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
Chloroethane	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
Methylene chloride	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
Acetone	25 U	20 U	23 U	12 U	12 U	12 U	45 U	7 J
Carbon disulfide	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
1,1-Dichloroethene	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
1,1-Dichloroethane	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
1,2-dichloroethene (Total)	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
Chloroform	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
1,2-Dichloroethane	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
Methyl ethyl ketone	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
1,1,1-Trichloroethane	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
Carbon tetrachloride	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
Bromodichloromethane	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
1,2-Dichloropropane	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
cis-1,3-Dichloropropene	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
Trichloroethene	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
Dibromochloromethane	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
1,1,2-Trichloroethane	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
Benzene	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
trans-1,3-Dichloropropene	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
Bromoform	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
4-Methyl-2-Pentanone	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
2-Hexanone	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
Tetrachloroethene	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
1,1,2,2-Tetrachloroethane	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
Toluene	11 U	2 J	12 U	12 U	12 U	12 U	11 U	12 U
Chlorobenzene	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
Ethylbenzene	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
Styrene	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U
Xylene (total)	11 U	12 U	12 U	12 U	12 U	12 U	11 U	12 U

## NOTES:

UG/KG indicates micrograms per kilogram

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

TABLE 5-1 (CONTINUED)

VOLATILE ORGANIC COMPOUNDS DETECTED IN SOIL SAMPLES  
 SITE 12  
 EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 AUGUST, 1995

SAMPLE NUMBER MATRIX UNITS	12SB-111-02 SOIL UG/KG	TRIP BLANK-2 WATER UG/L	TRIP BLANK-3 WATER UG/L	TRIP BLANK-4 WATER UG/L	TRIP BLANK-5 WATER UG/L	TRIP BLANK-6 WATER UG/L	12SB-RB1 WATER UG/L	12SB-RB2 WATER UG/L
Methyl chloride	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Methyl bromide	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Vinyl Chloride	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Chloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Methylene chloride	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Acetone	46 U	10 U	10 U	10 U	10 U	10 U	8 J	10 J
Carbon disulfide	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1-Dichloroethene	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1-Dichloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,2-dichloroethene (Total)	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Chloroform	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,2-Dichloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Methyl ethyl ketone	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1,1-Trichloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Carbon tetrachloride	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Bromodichloromethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,2-Dichloropropane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
cis-1,3-Dichloropropene	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Trichloroethene	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Dibromochloromethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1,2-Trichloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Benzene	10 U	10 U	10 U	10 U	10 U	10 U	10 U	1 J
trans-1,3-Dichloropropene	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Bromoform	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
4-Methyl-2-Pentanone	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
2-Hexanone	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Tetrachloroethene	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1,2,2-Tetrachloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Toluene	2 J	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Chlorobenzene	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Ethylbenzene	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Styrene	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Xylene (total)	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U

## NOTES:

UG/KG indicates micrograms per kilogram

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

05, which is the duplicate sample of 12SB-101-00, as well as 12SB-102-02, and 12SB-111-02 at 1 µg/kg (J), 4 µg/kg (J), 2 µg/kg (J), and 2 µg/kg (J).

## **SVOCs**

SVOCs were detected in three samples, 12SB-108-02, 12SB-109-02, and 12SB-111-02. **Table 5-2** contains a summary of SVOCs detected in subsurface soil and clay samples, and associated quality control samples, at Site 12. Samples 12SB-108-02 and 12SB-111-02 contained only bis(2-ethylhexyl)phthalate at 43 µg/kg (J) and 48 µg/kg (J), respectively. Eight SVOCs were detected in 12SB-109-02. Phenanthrene was detected at 55 µg/kg (J), di-n-butyl phthalate at 970 µg/kg, fluoranthene at 67 µg/kg (J), pyrene at 52 µg/kg (J), benzo(a)anthracene at 36 µg/kg (J), chrysene at 58 µg/kg (J), benzo(b)fluoranthene at 72 µg/kg (J), benzo(k)fluoranthene at 49 µg/kg (J), and benzo(a)pyrene at 36 µg/kg (J).

## **Pesticides and PCBs**

Pesticides and PCBs were detected in three of the five soil samples. **Table 5-3** contains a summary of pesticides and PCBs detected in soil samples, and associated quality control samples, at Site 12.

Heptachlor was detected in 12SB-108-02 at 0.88 µg/kg (J). 4,4'-DDE was detected in 12SB-109-02 at 1.7 µg/kg (J). 4,4'-DDD was detected in 12SB-108-02 at 1.8 µg/kg (J). 4,4'-DDT was detected in 12SB-108-02 and 12SB-109-02 at 3.5 µg/kg (J) and 3.6 µg/kg, respectively. alpha-chlordane was detected in 12SB-108-02, 12SB-107-03 (the duplicate of 12SB-107-02), 12SB-109-02, and 12SB-110-02 at 9.1 µg/kg, 2.1 µg/kg, 2.4 µg/kg (J), and 1.8 µg/kg (J), respectively. gamma-chlordane was detected in 12SB-108-02, 12SB-107-03 (the duplicate of 12SB-107-02), 12SB-109-02, and 12SB-110-02 at 9.7 µg/kg, 2.0 µg/kg, 2.2 µg/kg, and 1.7 µg/kg (J), respectively.

## **TAL Metals**

TAL metals were detected in all twelve soil samples analyzed. The following TAL metals were detected in the soil samples: aluminum, arsenic, barium, chromium, copper, iron, lead, manganese, nickel, vanadium, and zinc. Not all compounds were detected in each soil sample. **Table 5-4** presents a summary of TAL metals detected in soil and associated quality control samples at Site 12.

Aluminum was detected in all twelve soil samples at levels ranging from 390 mg/kg in 12SB-101-06 to 21,100 mg/kg in 12SB-111-02.

Arsenic was detected in eleven of the twelve soil samples at levels ranging from 1.3 mg/kg (J) in 12SB-102-04 to 4.6 mg/kg in 12SB-111-02.

Barium was detected in one sample, 12SB-103-02, at 52.7 mg/kg.

Chromium was detected in eleven of the twelve soil samples at levels ranging from 10.9 mg/kg in 12SB-102-00 to 24 mg/kg in 12SB-101-05, the duplicate sample of 12SB-101-00.

TABLE 5-2

SEMI-VOLATILE ORGANIC COMPOUNDS DETECTED IN SOIL SAMPLES  
 SITE 12  
 EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 AUGUST, 1995

SAMPLE NUMBER MATRIX UNITS	12SB-08-02 SOIL UG/KG	12SB-107-02 SOIL UG/KG	12SB-107-03 SOIL UG/KG	12SB-109-02 SOIL UG/KG	12SB-110-02 SOIL UG/KG	12SB-111-02 SOIL UG/KG	12SB-RB1 WATER UG/L
Phenol	410 U	380 U	390 U	350 U	410 U	350 U	11 U
bis(2-Chloroethyl) Ether	410 U	380 U	390 U	350 U	410 U	350 U	11 U
2-Chlorophenol	410 U	380 U	390 U	350 U	410 U	350 U	11 U
1,3-Dichlorobenzene	410 U	380 U	390 U	350 U	410 U	350 U	11 U
1,4-Dichlorobenzene	410 U	380 U	390 U	350 U	410 U	350 U	11 U
1,2-Dichlorobenzene	410 U	380 U	390 U	350 U	410 U	350 U	11 U
2-Methylphenol	410 U	380 U	390 U	350 U	410 U	350 U	11 U
bis(2-Chloroisopropyl) Ether	410 U	380 U	390 U	350 U	410 U	350 U	11 U
4-Methylphenol	410 U	380 U	390 U	350 U	410 U	350 U	11 U
N-Nitrosodipropylamine	410 U	380 U	390 U	350 U	410 U	350 U	11 U
Hexachloroethane	410 U	380 U	390 U	350 U	410 U	350 U	11 U
Nitrobenzene	410 U	380 U	390 U	350 U	410 U	350 U	11 U
Isophorone	410 U	380 U	390 U	350 U	410 U	350 U	11 U
2-Nitrophenol	410 U	380 U	390 U	350 U	410 U	350 U	11 U
2,4-Dimethylphenol	410 U	380 U	390 U	350 U	410 U	350 U	11 U
bis(2-Chloroethoxy)Methanol	410 U	380 U	390 U	350 U	410 U	350 U	11 U
2,4-Dichlorophenol	410 U	380 U	390 U	350 U	410 U	350 U	11 U
1,2,4-Trichlorobenzene	410 U	380 U	390 U	350 U	410 U	350 U	11 U
Naphthalene	410 U	380 U	390 U	350 U	410 U	350 U	11 U
4-Chloroaniline	410 U	380 U	390 U	350 U	410 U	350 U	11 U
Hexachlorobutadiene	410 U	380 U	390 U	350 U	410 U	350 U	11 U
4-Chloro-3-methylphenol	410 U	380 U	390 U	350 U	410 U	350 U	11 U
2-Methylnaphthalene	410 U	380 U	390 U	350 U	410 U	350 U	11 U
Hexachlorocyclopentadiene	410 U	380 U	390 U	350 U	410 U	350 U	11 U
2,4,6-Trichlorophenol	410 U	380 U	390 U	350 U	410 U	350 U	11 U
2,4,5-Trichlorophenol	1000 U	930 U	940 U	860 U	990 U	860 U	28 U
2-Chloronaphthalene	410 U	380 U	390 U	350 U	410 U	350 U	11 U
2-Nitroaniline	1000 U	930 U	940 U	860 U	990 U	860 U	28 U
Dimethylphthalate	410 U	380 U	390 U	350 U	410 U	350 U	11 U
Acenaphthylene	410 U	380 U	390 U	350 U	410 U	350 U	11 U
2,6-Dinitrotoluene	410 U	380 U	390 U	350 U	410 U	350 U	11 U
3-Nitroaniline	1000 U	930 U	940 U	860 U	990 U	860 U	28 U

## NOTES:

UG/KG indicates micrograms per kilogram

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

TABLE 5-2 (CONTINUED)

SEMI-VOLATILE ORGANIC COMPOUNDS DETECTED IN SOIL SAMPLES  
 SITE 12  
 EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 AUGUST, 1995

SAMPLE NUMBER MATRIX UNITS	12SB-08-02 SOIL UG/KG	12SB-107-02 SOIL UG/KG	12SB-107-03 SOIL UG/KG	12SB-109-02 SOIL UG/KG	12SB-110-02 SOIL UG/KG	12SB-111-02 SOIL UG/KG	12SB-RB1 WATER UG/L
Acenaphthene	410 U	380 U	390 U	350 U	410 U	350 U	11 U
2,4-Dinitrophenol	1000 U	930 U	940 U	860 U	990 U	860 U	28 U
4-Nitrophenol	1000 U	930 U	940 U	860 U	990 U	860 U	28 U
Dibenzofuran	410 U	380 U	390 U	350 U	410 U	350 U	11 U
2,4-Dinitrotoluene	410 U	380 U	390 U	350 U	410 U	350 U	11 U
Diethylphthalate	410 U	380 U	390 U	350 U	410 U	350 U	11 U
4-Chlorophenylphenyl Ether	410 U	380 U	390 U	350 U	410 U	350 U	11 U
Fluorene	410 U	380 U	390 U	350 U	410 U	350 U	11 U
4-Nitroaniline	1000 U	930 U	940 U	860 U	990 U	860 U	28 U
4,6-Dinitro-2-Methylphenol	1000 U	930 U	940 U	860 U	990 U	860 U	28 U
N-nitrosodiphenylamine	410 U	380 U	390 U	350 U	410 U	350 U	11 U
4-Bromophenylphenyl Ether	410 U	380 U	390 U	350 U	410 U	350 U	11 U
Hexachlorobenzene	410 U	380 U	390 U	350 U	410 U	350 U	11 U
Pentachlorophenol	1000 U	930 U	940 U	860 U	990 U	860 U	28 U
Phenanthrene	410 U	380 U	390 U	55 J	410 U	350 U	11 U
Anthracene	410 U	380 U	390 U	350 U	410 U	350 U	11 U
Carbazole	410 U	380 U	390 U	350 U	410 U	350 U	11 U
Di-n-Butyl Phthalate	410 U	380 U	390 U	970	410 U	350 U	11 U
Fluoranthene	410 U	380 U	390 U	67 J	410 U	350 U	11 U
Pyrene	410 U	380 U	390 U	52 J	410 U	350 U	11 U
Butyl Benzyl Phthalate	410 U	380 U	390 U	350 U	410 U	350 U	11 U
3,3'-Dichlorobenzidine	410 U	380 U	390 U	350 U	410 U	350 U	11 U
Benzo(a)anthracene	410 U	380 U	390 U	36 J	410 U	350 U	11 U
Chrysene	410 U	380 U	390 U	58 J	410 U	350 U	11 U
bis(2-Ethylhexyl)Phthalate	43 J	380 U	390 U	350 U	410 U	48 J	11 U
Di-n-Octylphthalate	410 U	380 U	390 UJ	350 U	410 UJ	350 U	11 U
Benzo(b)fluoranthene	410 U	380 U	390 UJ	72 J	410 UJ	350 U	11 U
Benzo(k)fluoranthene	410 U	380 U	390 UJ	49 J	410 UJ	350 U	11 U
Benzo(a)Pyrene	410 U	380 U	390 UJ	36 J	410 UJ	350 U	11 U
Indeno(1,2,3-cd)pyrene	410 U	380 U	390 UJ	350 U	410 UJ	350 U	11 U
Dibenzo(a,h)anthracene	410 U	380 U	390 UJ	350 U	410 UJ	350 U	11 U
Benzo(g,h,i)Perylene	410 U	380 U	390 UJ	350 U	410 UJ	350 U	11 U

## NOTES:

UG/KG indicates micrograms per kilogram

UG/L indicates microgram per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

TABLE 5-3

PESTICIDES/PCBs DETECTED IN SOIL SAMPLES  
 SITE 12  
 EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 AUGUST, 1995

SAMPLE NUMBER MATRIX UNITS	12SB-108-02 SOIL UG/KG	12SB-107-02 SOIL UG/KG	12SB-107-03 SOIL UG/KG	12SB-109-02 SOIL UG/KG	12SB-110-02 SOIL UG/KG	12SB-111-02 SOIL UG/KG	12SB-RB1 WATER UG/L
alpha-BHC	2.1 U	2.0 U	2.0 U	1.8 U	2.1 U	1.8 U	0.05 U
beta-BHC	2.1 U	2.0 U	2.0 U	1.8 U	2.1 U	1.8 U	0.05 U
delta-BHC	2.1 U	2.0 U	2.0 U	1.8 U	2.1 U	1.8 U	0.05 U
gamma-BHC (Lindane)	2.1 U	2.0 U	2.0 U	1.8 U	2.1 U	1.8 U	0.05 U
Heptachlor	0.88 J	2.0 U	2.0 U	1.8 U	2.1 U	1.8 U	0.05 U
Aldrin	2.1 U	2.0 U	2.0 U	1.8 U	2.1 U	1.8 U	0.05 U
Heptachlor Epoxide	2.1 U	2.0 U	2.0 U	1.8 U	2.1 U	1.8 U	0.05 U
Endosulfan I	2.1 U	2.0 U	2.0 U	1.8 U	2.1 U	1.8 U	0.05 U
Dieldrin	4.1 U	3.8 U	3.9 U	3.5 U	4.1 U	3.5 U	0.10 U
4,4'-DDE	4.1 U	3.8 U	3.9 U	1.7 J	4.1 U	3.5 U	0.10 U
Endrin	4.1 U	3.8 U	3.9 U	3.5 U	4.1 U	3.5 U	0.10 U
Endosulfan II	4.1 U	3.8 U	3.9 U	3.5 U	4.1 U	3.5 U	0.10 U
4,4'-DDD	1.8 J	3.8 U	3.9 U	3.5 U	4.1 U	3.5 U	0.10 U
Endosulfan Sulfate	4.1 U	3.8 U	3.9 U	3.5 U	4.1 U	3.5 U	0.10 U
4,4'-DDT	3.5 J	3.8 U	3.9 U	3.6	4.1 U	3.5 U	0.10 U
Methoxychlor	21 U	20 U	20 U	18 U	21 U	18 U	0.50 U
Endrin Ketone	4.1 U	3.8 U	3.9 U	3.5 U	4.1 U	3.5 U	0.10 U
Endrin Aldehyde	4.1 U	3.8 U	3.9 U	3.5 U	4.1 U	3.5 U	0.10 U
alpha-Chlordane	9.1	2.0 U	2.1	2.4 J	1.8 J	1.8 U	0.050 U
gamma-Chlordane	9.7	2.0 U	2.0	2.2	1.7 J	1.8 U	0.050 U
Toxaphene	210 U	200 U	200 U	180 U	210 U	180 U	5.0 U
Aroclor 1016	41 U	38 U	39 U	35 U	41 U	35 U	1.0 U
Aroclor 1221	84 U	78 U	79 U	72 U	83 U	72 U	2.0 U
Aroclor 1232	41 U	38 U	39 U	35 U	41 U	35 U	1.0 U
Aroclor 1242	41 U	38 U	39 U	35 U	41 U	35 U	1.0 U
Aroclor-1248	41 U	38 U	39 U	35 U	41 U	35 U	1.0 U
Aroclor-1254	41 U	38 U	39 U	35 U	41 U	35 U	1.0 U
Aroclor-1260	41 U	38 U	39 U	35 U	41 U	35 U	1.0 U

**NOTES:**

UG/KG indicates micrograms per kilogram

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank



**TABLE 5-4**  
**INORGANIC COMPOUNDS DETECTED IN SOIL SAMPLES**  
**SITE 12**  
**EXCHANGE LAUNDRY WASTE DISPOSAL AREA**  
**NAVAL AMPHIBIOUS BASE LITTLE CREEK**  
**VIRGINIA BEACH, VIRGINIA**  
**AUGUST, 1995**

<b>SAMPLE NUMBER</b>	<b>12SB-101-00</b>	<b>12SB-101-02</b>	<b>12SB-101-05</b>	<b>12SB-101-06</b>	<b>12SB-102-00</b>	<b>12SB-102-02</b>	<b>12SB-102-04</b>	<b>12SB-103-02</b>
<b>MATRIX</b>	<b>SOIL</b>	<b>SOIL</b>	<b>SOIL</b>	<b>SOIL</b>	<b>SOIL</b>	<b>SOIL</b>	<b>SOIL</b>	<b>SOIL</b>
<b>UNITS</b>	<b>MG/KG</b>	<b>MG/KG</b>	<b>MG/KG</b>	<b>MG/KG</b>	<b>MG/KG</b>	<b>MG/KG</b>	<b>MG/KG</b>	<b>MG/KG</b>
Aluminum	18800.00	10400.00	19300.00	390.00	9740.00	12400.00	13500.00	18400.00
Antimony	3.50 UJ	3.50 UJ	3.50 UJ	3.10 UJ	3.40 UJ	3.40 UJ	3.60 UJ	3.40 UJ
Arsenic	4.30	2.70J	4.00	1.20 B	2.30 J	2.00 J	1.30 J	3.90
Barium	41.90 B	29.40 B	40.00 B	1.40 B	29.20 B	38.70 B	32.90 B	52.70
Beryllium	0.31 B	0.15 B	0.34 B	0.07 B	0.28 B	0.30 B	0.20 B	0.33 B
Cadmium	0.40 U	0.40 U	0.40 U	0.36 U	0.39 U	0.40 U	0.41 U	0.39 U
Calcium	345.00 B	88.20 B	426.00 B	41.50 B	174.00 B	118.00 B	124.00 B	424.00 B
Chromium	19.70	12.00	24.00	2.10 B	10.90	12.10	12.70	18.90
Cobalt	4.80 B	1.40 B	4.40 B	0.43 U	1.60 B	2.40 B	2.10 B	3.00 B
Copper	5.80 B	4.10 B	6.10	1.00 U	3.50 B	3.60 B	3.40 B	4.00 B
Iron	18000.00	5890.00	19000.00	1350.00	8050.00	9590.00	6380.00	15200.00
Lead	9.40	6.80	9.90	0.49 B	5.70	7.50	7.10	9.40
Magnesium	1030.00 B	530.00 B	1120.00 B	31.30 B	614.00 B	816.00 B	765.00 B	988.00 B
Manganese	39.50	9.60	40.20	0.95 B	24.60	27.60	18.90	37.90
Mercury	0.12 U	0.12 U	0.12 U	0.11 U	0.11 U	0.12 U	0.12 U	0.12 U
Nickel	6.70 B	3.40 B	6.60 B	1.10 U	3.10 B	5.20 B	4.40 B	7.10 B
Potassium	563.00 B	450.00 B	504.00 B	76.80 U	365.00 B	384.00 B	404.00 B	484.00 B
Selenium	0.71 B	0.64 U	0.87 B	0.57 U	0.62 U	0.63 U	0.66 U	0.63 U
Silver	0.66 B	0.64 U	0.64 U	0.57 U	0.62 U	0.63 U	0.66 U	0.63 U
Sodium	89.20 B	85.60 B	103.00 B	52.40 U	76.30 B	97.80 B	94.10 B	143.00 B
Thallium	0.97 U	0.96 U	0.97 U	0.87 U	0.94 U	0.95 U	1.00 U	0.95 U
Vanadium	29.30J	23.70 J	29.40 J	2.20 BJ	15.00 J	18.40 J	21.30 J	27.80 J
Zinc	17.00	6.00	18.60	3.20 B	8.40	13.00	9.30	12.20
Cyanide	3.00 U	2.90 U	3.00 U	2.70 U	2.90 U	2.90 U	3.00 U	2.90 U

**NOTES:**

UG/KG indicates micrograms per kilogram

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

L indicates results biased low

**TABLE 5-4 (CONTINUED)**  
**INORGANIC COMPOUNDS DETECTED IN SOIL SAMPLES**  
**SITE 12**  
**EXCHANGE LAUNDRY WASTE DISPOSAL AREA**  
**NAVAL AMPHIBIOUS BASE LITTLE CREEK**  
**VIRGINIA BEACH, VIRGINIA**  
**AUGUST, 1995**

<b>SAMPLE NUMBER MATRIX UNITS</b>	<b>12SB-107-02 SOIL MG/KG</b>	<b>12SB-107-03 SOIL MG/KG</b>	<b>12SB-08-02 SOIL MG/KG</b>	<b>12SB-109-02 SOIL MG/KG</b>	<b>12SB-110-02 SOIL MG/KG</b>	<b>12SB-111-02 SOIL MG/KG</b>	<b>12SB-RB1 WATER MG/L</b>	<b>12SB-RB2 WATER UG/L</b>
Aluminum	12700.00	15700	10600.00	7810	11300	21100	14.4 U	14.4 U
Antimony	3.40 UJ	3.5 U	3.70 UJ	3.2 U	3.7 U	3.2 UJ	14.8 U	14.8 U
Arsenic	3.00 JL	2.9	2.20 J	2.6	3.0	4.6	1.3 U	1.3 U
Barium	27.90 B	33.3 B	28.30 B	35.7 B	33.1 B	38.5 B	1.2 U	0.87 U
Beryllium	0.23 B	0.23 B	0.15 B	0.33 B	0.25 B	0.31 B	0.33 U	0.36 U
Cadmium	0.40 U	0.40 U	0.42 U	0.37 U	0.42 U	0.36 U	1.7 U	1.7 U
Calcium	149.00 B	179 B	295.00 B	965 B	502 B	97.3 B	11.1 U	11.1 U
Chromium	14.80	17.2	11.90	13.4	11.2	21.0	1.6 U	1.6 U
Cobalt	2.20 B	2.9 B	1.70 B	2.8 B	3.1 B	5.1 B	2.0 U	2.0 U
Copper	4.30 B	4.6 B	3.60 B	6.7	6.2 B	7.2	4.7 U	4.7 U
Iron	7850.00	9480	6340.00	8060	7520	18300	4.6 U	7.8 U
Lead	7.00	8.3	6.70	11.7	8.0	9.6	1.6 U	1.6 U
Magnesium	692.00 B	855 B	582.00 B	824 B	638 B	1050 B	15.4 U	15.4 U
Manganese	16.20	19.3	15.90	57	34.6	45.7	0.50 U	0.50 U
Mercury	0.12 U	0.12 U	0.12 U	0.11 U	0.12 U	0.11 U	0.20 U	0.20 U
Nickel	5.00 B	6.1 B	2.60 B	12.7	6.4 B	7.9 B	5.4 U	5.4 U
Potassium	543.00 B	626 B	377.00 B	588 B	376 B	534 B	482 U	361 U
Selenium	0.63 U	0.63 U	0.67 U	0.66 B	0.67 U	0.70 B	2.7 U	2.7 U
Silver	0.63 U	0.63 U	0.67 U	0.58 U	0.67 U	0.58 U	2.7 U	2.7 U
Sodium	80.80 B	92.4 B	103.00 B	94.0 B	96.1 B	107 B	99.8 U	71.9 U
Thallium	0.95 U	0.96 U	1.00 U	0.88 U	1.0 U	0.88 U	4.1 U	5.4 B
Vanadium	19.20 J	21.8	21.8J	13.5 J	18.9 J	28.0 J	0.90 U	0.90 U
Zinc	10.70	13	11.50	16.9	12.8	19.0	8.5 B	6.7 U
Cyanide	2.90 U	2.9 U	3.10 U	2.7 U	3.1 U	2.7 U	5.0 U	5.0 U

**NOTES:**

UG/KG indicates micrograms per kilogram

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

L indicates results biased low

Copper was detected in three of the twelve soil samples at levels ranging from 6.1 mg/kg in 12SB-101-05, the duplicate of 12-SB-101-00, to 7.2 mg/kg in 12SB-111-02.

Iron was detected in all twelve soil samples at levels ranging from 1,350 mg/kg in 12SB-101-06 to 19,000 mg/kg in the duplicate sample of 12SB-101-00.

Lead was detected in eleven of the twelve soil samples at levels ranging from 5.7 mg/kg in 12SB-102-00 to 11.7 mg/kg in 12SB-109-02.

Manganese was detected in eleven of the twelve soil samples at levels ranging from 9.6 mg/kg in 12SB-101-02 to 57 mg/kg in 12SB-109-02.

Nickel was detected in one sample, 12SB-109-02, at 12.7 mg/kg.

Vanadium was detected in eleven of the twelve soil samples at levels ranging from 13.5 mg/kg (J) in 12SB-109-02 to 29.4 mg/kg (J) in 12SB-101-05, the duplicate sample of 12SB-101-00.

Zinc was detected in eleven of the twelve soil samples at levels ranging from 6 mg/kg in 12SB-101-02 to 19 mg/kg in 12SB-111-02.

### Groundwater

Nine groundwater samples were collected from the nine groundwater monitoring wells at Site 12. These samples were analyzed for VOCs, SVOCs, pesticides and PCBs, TAL total and dissolved metals, and anions.

### **VOCs**

Eight of the nine groundwater samples analyzed contained VOCs. **Table 5-5** contains a summary of VOCs detected in groundwater samples, and associated quality control samples, at Site 12. The following VOCs were detected in the groundwater samples, though each compound was not detected in each sample: 1,2-dichloroethene (total), tetrachloroethene, trichloroethene, and vinyl chloride.

1,2-dichloroethene (total) was detected in two samples at the following levels: 4 µg/l (J) in LC12-GW106 and 15 µg/l (J) in LC12-GW107. 1,2-dichloroethene (total) also was detected at a level of 7 µg/l (J) in LC12-GW110, the duplicate sample of LC12-GW108, though not in LC12-GW108 itself.

Tetrachloroethene was detected in six of the nine groundwater samples at levels ranging from 4 µg/l (J) in LC12-GW103 to 1,600 µg/l in LC12-GW105.

Trichloroethene was detected in seven of the nine groundwater samples at levels ranging from 1 µg/l (J) in LC12-GW103 to 760 µg/l in LC12-GW104.

Vinyl chloride was detected in one sample, LC12-GW104, at 980 µg/l.

TABLE 5-5

VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER SAMPLES  
 SITE 12  
 EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 AUGUST, 1995

SAMPLE NUMBER MATRIX UNITS	LC12-GW101 WATER UG/L	LC12-GW102 WATER UG/L	LC12-GW103 WATER UG/L	LC12-GW104 WATER UG/L	LC12-GW105 WATER UG/L	LC12-GW106 WATER UG/L	LC12-GW107 WATER UG/L	LC12-GW108 WATER UG/L
Methyl chloride	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
Methyl bromide	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
Vinyl Chloride	10 U	10 U	10 U	980	100 U	10 U	50 U	10 U
Chloroethane	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
Methylene chloride	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
Acetone	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
Carbon disulfide	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
1,1-Dichloroethene	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
1,1-Dichloroethane	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
1,2-dichloroethene (Total)	10 U	10 U	10 U	11000 R	100 U	4 J	15 J	10 U
Chloroform	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
1,2-Dichloroethane	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
Methyl ethyl ketone	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
1,1,1-Trichloroethane	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
Carbon tetrachloride	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
Bromodichloromethane	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
1,2-Dichloropropane	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
cis-1,3-Dichloropropene	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
Trichloroethene	2 J	10 U	1 J	760	26 J	12	18 J	2 J
Dibromochloromethane	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
1,1,2-Trichloroethane	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
Benzene	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
trans-1,3-Dichloropropene	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
Bromoform	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
4-Methyl-2-Pentanone	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
2-Hexanone	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
Tetrachloroethene	10 U	10 U	4 J	790	1600	200 R	580	38
1,1,2,2-Tetrachloroethane	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
Toluene	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
Chlorobenzene	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
Ethylbenzene	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
Styrene	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U
Xylene (total)	10 U	10 U	10 U	250 U	100 U	10 U	50 U	10 U

## NOTES:

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

R indicates sample rejected

TABLE 5-5 (CONTINUED)

VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER SAMPLES  
 SITE 12  
 EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 AUGUST, 1995

SAMPLE NUMBER MATRIX UNITS	LC12-GW109 WATER UG/L	LC12-GW110 WATER UG/L	LC12-GW-FB WATER UG/L	LC12-GW-RB WATER UG/L	LC12-GWTB2 WATER UG/L	LC12-GWTB3 WATER UG/L	LC12-GWTB4 WATER UG/L
Methyl chloride	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Methyl bromide	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Vinyl Chloride	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Chloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Methylene chloride	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Acetone	10 U	10 U	2 J	10 U	10 U	2 J	4 J
Carbon disulfide	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1-Dichloroethene	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1-Dichloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,2-dichloroethene (Total)	10 U	7 J	10 U	10 U	10 U	10 U	10 U
Chloroform	10 U	10 U	2 J	3 J	10 U	3 J	3 J
1,2-Dichloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Methyl ethyl ketone	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1,1-Trichloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Carbon tetrachloride	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Bromodichloromethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,2-Dichloropropane	10 U	10 U	10 U	10 U	10 U	10 U	10 U
cis-1,3-Dichloropropene	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Trichloroethene	10 U	16	10 U	10 U	10 U	10 U	10 U
Dibromochloromethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1,2-Trichloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Benzene	10 U	10 U	10 U	10 U	10 U	10 U	10 U
trans-1,3-Dichloropropene	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Bromoform	10 U	10 U	10 U	10 U	10 U	10 U	10 U
4-Methyl-2-Pentanone	10 U	10 U	10 U	10 U	10 U	10 U	10 U
2-Hexanone	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Tetrachloroethene	15	370 D	10 U	10 U	10 U	10 U	10 U
1,1,2,2-Tetrachloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Toluene	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Chlorobenzene	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Ethylbenzene	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Styrene	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Xylene (total)	10 U	10 U	10 U	10 U	10 U	10 U	10 U

## NOTES:

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

D indicates sample diluted

## **SVOCs**

Two of the nine groundwater samples analyzed contained SVOCs. **Table 5-6** contains a summary of SVOCs detected in groundwater samples, and associated quality control samples, at Site 12.

Bis(2-ethylhexyl)phthalate, a common laboratory contaminant, was detected in sample LC12-GW103 and LC12-GW104 at 1  $\mu\text{g/l}$  (J), as well as LC12-GW110, the duplicate sample of LC12-GW108, at 0.9  $\mu\text{g/l}$  (J), though not in LC12-GW108 itself. Fluoranthene, phenanthrene, and pyrene were each detected in LC12-GW104 at 1  $\mu\text{g/l}$  (J).

## **Pesticides and PCBs**

Pesticides and PCBs were detected in two of the nine groundwater samples. **Table 5-7** contains a summary of pesticides and PCBs detected in groundwater samples, and associated quality control samples, at Site 12.

Aldrin was detected in LC12-GW102 at 0.015  $\mu\text{g/l}$  (J). Heptachlor epoxide, alpha-chlordane, and gamma-chlordane were detected in LC12-GW105 at 0.038  $\mu\text{g/l}$  (J), 0.081  $\mu\text{g/l}$  (J), and 0.046  $\mu\text{g/l}$  (J), respectively.

## **Total and Dissolved TAL Metals**

Total and dissolved TAL metals were detected in all nine of the groundwater samples. **Table 5-8** presents a summary of TAL total and dissolved metals detected in groundwater samples and associated quality control samples at Site 12.

The following TAL metals were detected in the nine groundwater samples collected at Site 12, though each compound was not detected in each sample: total aluminum, total arsenic, total barium, total beryllium, total and dissolved cadmium, total and dissolved calcium, total chromium, total cobalt, total copper, total and dissolved iron, total and dissolved lead, total and dissolved magnesium, total and dissolved manganese, total mercury, total nickel, total potassium, total and dissolved sodium, total vanadium, total and dissolved zinc, and cyanide.

Total aluminum was detected in all nine groundwater samples at levels ranging from 15,200  $\mu\text{g/l}$  in LC12-GW106 to 96,700  $\mu\text{g/l}$  in LC12-GW102.

Total arsenic was detected in all nine groundwater samples at levels ranging from 17.7  $\mu\text{g/l}$  in LC12-GW106 to 125  $\mu\text{g/l}$  in LC12-GW102.

Total barium was detected in five of the nine groundwater samples at levels ranging from 210  $\mu\text{g/l}$  in LC12-GW102 to 478  $\mu\text{g/l}$  in LC12-GW108.

Total beryllium was detected in one sample, LC12-GW109, at 5.1  $\mu\text{g/l}$ .

TABLE 5-6

SEMI-VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER SAMPLES  
 SITE 12  
 EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 AUGUST, 1995

SAMPLE NUMBER MATRIX UNITS	LC12-GW101 WATER UG/L	LC12-GW102 WATER UG/L	LC12-GW103 WATER UG/L	LC12-GW103 MS WATER UG/L	LC12-GW103 MSD WATER UG/L	LC12-GW104 WATER UG/L	LC12-GW105 WATER UG/L
Phenol	10 U	10 U	10 U	87	100	10 U	10 U
bis(2-Chloroethyl) Ether	10 U	10 U	10 U	20 U	20 U	10 U	10 U
2-Chlorophenol	10 U	10 U	10 U	98	110	10 U	10 U
1,3-Dichlorobenzene	10 U	10 U	10 U	20 U	20 U	10 U	10 U
1,4-Dichlorobenzene	10 U	10 U	10 U	68	67	10 U	10 U
1,2-Dichlorobenzene	10 U	10 U	10 U	20 U	20 U	10 U	10 U
2-Methylphenol	10 U	10 U	10 U	20 U	20 U	10 U	10 U
bis(2-Chloroisopropyl)Ether	10 U	10 U	10 U	20 U	20 U	10 U	10 U
4-Methylphenol	10 U	10 U	10 U	20 U	20 U	10 U	10 U
N-Nitrosodipropylamine	10 U	10 U	10 U	45	61	10 U	10 U
Hexachloroethane	10 U	10 U	10 U	20 U	20 U	10 U	10 U
Nitrobenzene	10 U	10 U	10 U	20 U	20 U	10 U	10 U
Isophorone	10 U	10 U	10 U	20 U	20 U	10 U	10 U
2-Nitrophenol	10 U	10 U	10 U	20 U	20 U	10 U	10 U
2,4-Dimethylphenol	10 U	10 U	10 U	20 U	20 U	10 U	10 U
bis(2-Chloroethoxy)Methanol	10 U	10 U	10 U	20 U	20 U	10 U	10 U
2,4-Dichlorophenol	10 U	10 U	10 U	20 U	20 U	10 U	10 U
1,2,4-Trichlorobenzene	10 U	10 U	10 U	79	74	10 U	10 U
Naphthalene	10 U	10 U	10 U	20 U	20 U	10 U	10 U
4-Chloroaniline	10 U	10 U	10 U	20 U	20 U	10 U	10 U
Hexachlorobutadiene	10 U	10 U	10 U	20 U	20 U	10 U	10 U
4-Chloro-3-methylphenol	10 U	10 U	10 U	110	120	10 U	10 U
2-Methylnaphthalene	10 U	10 U	10 U	20 U	20 U	10 U	10 U
Hexachlorocyclopentadiene	10 U	10 U	10 U	20 U	20 U	10 U	10 U
2,4,6-Trichlorophenol	10 U	10 U	10 U	20 U	20 U	10 U	10 U
2,4,5-Trichlorophenol	25 U	25 U	25 U	50 U	50 U	25 U	25 U
2-Chloronaphthalene	10 U	10 U	10 U	20 U	20 U	10 U	10 U
2-Nitroaniline	25 U	25 U	25 U	50 U	50 U	25 U	25 U
Dimethylphthalate	10 U	10 U	10 U	20 U	20 U	10 U	10 U
Acenaphthylene	10 U	10 U	10 U	20 U	20 U	10 U	10 U
2,6-Dinitrotoluene	10 U	10 U	10 U	20 U	20 U	10 U	10 U
3-Nitroaniline	25 U	25 U	25 U	50 U	50 U	25 U	25 U

## NOTES:

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

TABLE 5-6 (CONTINUED)

SEMI-VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER SAMPLES  
 SITE 12  
 EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 AUGUST, 1995

SAMPLE NUMBER MATRIX UNITS	LC12-GW101 WATER UG/L	LC12-GW102 WATER UG/L	LC12-GW103 WATER UG/L	LC12-GW103 MS WATER UG/L	LC12-GW103 MSD WATER UG/L	LC12-GW104 WATER UG/L	LC12-GW105 WATER UG/L
Acenaphthene	10 U	10 U	10 U	70	75	10 U	10 U
2,4-Dinitrophenol	25 U	25 U	25 U	50 U	50 U	25 U	25 U
4-Nitrophenol	25 U	25 U	25 U	120	140	25 U	25 U
Dibenzofuran	10 U	10 U	10 U	20 U	20 U	10 U	10 U
2,4-Dinitrotoluene	10 U	10 U	10 U	89	77	10 U	10 U
Diethylphthalate	10 U	10 U	10 U	20 U	20 U	10 U	10 U
4-Chlorophenylphenyl Ether	10 U	10 U	10 U	20 U	20 U	10 U	10 U
Fluorene	10 U	10 U	10 U	20 U	20 U	10 U	10 U
4-Nitroaniline	25 U	25 U	25 U	50 U	50 U	25 U	25 U
4,6-Dinitro-2-Methylphenol	25 U	25 U	25 U	50 U	50 U	25 U	25 U
N-nitrosodiphenylamine	10 U	10 U	10 U	20 U	20 U	10 U	10 U
4-Bromophenylphenyl Ether	10 U	10 U	10 U	20 U	20 U	10 U	10 U
Hexachlorobenzene	10 U	10 U	10 U	20 U	20 U	10 U	10 U
Pentachlorophenol	25 U	25 U	25 U	150	130	25 U	25 U
Phenanthrene	10 U	10 U	10 U	20 U	20 U	1 J	10 U
Anthracene	10 U	10 U	10 U	20 U	20 U	10 U	10 U
Carbazole	10 U	10 U	10 U	20 U	20 UJ	10 U	10 U
Di-n-Butyl Phthalate	10 U	10 U	10 U	20 U	20 U	10 U	10 U
Fluoranthene	10 U	10 U	10 U	20 U	20 U	1 J	10 U
Pyrene	10 U	10 U	10 U	79	84	1 J	10 U
Butyl Benzyl Phthalate	10 U	10 U	10 U	20 U	20 U	10 U	10 U
3,3'-Dichlorobenzidine	10 U	10 U	10 U	20 U	20 U	10 U	10 U
Benzo(a)anthracene	10 U	10 U	10 U	20 U	20 U	10 U	10 U
Chrysene	10 U	10 U	10 U	20 U	20 U	10 U	10 U
bis(2-Ethylhexyl)Phthalate	10 U	10 U	1 J	20 U	20 U	1 J	10 U
Di-n-Octylphthalate	10 U	10 U	10 U	20 U	20 U	10 U	10 U
Benzo(b)fluoranthene	10 U	10 U	10 U	20 U	20 U	10 U	10 U
Benzo(k)fluoranthene	10 U	10 U	10 U	20 U	20 U	10 U	10 U
Benzo(a)Pyrene	10 U	10 U	10 U	20 U	20 U	10 U	10 U
Indeno(1,2,3-cd)pyrene	10 U	10 U	10 U	20 U	20 U	10 U	10 U
Dibenzo(a,h)anthracene	10 U	10 U	10 U	20 U	20 U	10 U	10 U
Benzo(g,h,i)Perylene	10 U	10 U	10 U	20 U	20 U	10 U	10 U

**NOTES:**

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank



TABLE 5-6 (CONTINUED)

SEMI-VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER SAMPLES  
 SITE 12  
 EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 AUGUST, 1995

SAMPLE NUMBER MATRIX UNITS	LC12-GW106 WATER UG/L	LC12-GW107 WATER UG/L	LC12-GW108 WATER UG/L	LC12-GW109 WATER UG/L	LC12-GW110 WATER UG/L	LC12-GW-FB WATER UG/L	LC12-GW-RB WATER UG/L
Phenol	10 U	10 U	10 U	10 U	10 U	11 U	12 U
bis(2-Chloroethyl) Ether	10 U	10 U	10 U	10 U	10 U	11 U	12 U
2-Chlorophenol	10 U	10 U	10 U	10 U	10 U	11 U	12 U
1,3-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U	11 U	12 U
1,4-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U	11 U	12 U
1,2-Dichlorobenzene	10 U	10 U	10 U	10 U	10 U	11 U	12 U
2-Methylphenol	10 U	10 U	10 U	10 U	10 U	11 U	12 U
bis(2-Chloroisopropyl)Ether	10 U	10 U	10 U	10 UJ	10 U	11 U	12 U
4-Methylphenol	10 U	10 U	10 U	10 U	10 U	11 U	12 U
N-Nitrosodipropylamine	10 U	10 U	10 U	10 U	10 U	11 U	12 U
Hexachloroethane	10 U	10 U	10 U	10 U	10 U	11 U	12 U
Nitrobenzene	10 U	10 U	10 U	10 U	10 U	11 U	12 U
Isophorone	10 U	10 U	10 U	10 U	10 U	11 U	12 U
2-Nitrophenol	10 U	10 U	10 U	10 U	10 U	11 U	12 U
2,4-Dimethylphenol	10 U	10 U	10 U	10 U	10 U	11 U	12 U
bis(2-Chloroethoxy)Methanol	10 U	10 U	10 U	10 U	10 U	11 U	12 U
2,4-Dichlorophenol	10 U	10 U	10 U	10 U	10 U	11 U	12 U
1,2,4-Trichlorobenzene	10 U	10 U	10 U	10 U	10 U	11 U	12 U
Naphthalene	10 U	10 U	10 U	10 U	10 U	11 U	12 U
4-Chloroaniline	10 U	10 U	10 U	10 U	10 U	11 U	12 U
Hexachlorobutadiene	10 U	10 U	10 U	10 U	10 U	11 U	12 U
4-Chloro-3-methylphenol	10 U	10 U	10 U	10 U	10 U	11 U	12 U
2-Methylnaphthalene	10 U	10 U	10 U	10 U	10 U	11 U	12 U
Hexachlorocyclopentadiene	10 U	10 U	10 U	10 U	10 U	11 U	12 U
2,4,6-Trichlorophenol	10 U	10 U	10 U	10 U	10 U	11 U	12 U
2,4,5-Trichlorophenol	25 U	25 U	25 U	25 U	25 U	28 U	29 U
2-Chloronaphthalene	10 U	10 U	10 U	10 U	10 U	11 U	12 U
2-Nitroaniline	25 U	25 U	25 U	25 U	25 U	28 U	29 U
Dimethylphthalate	10 U	10 U	10 U	10 U	10 U	11 U	12 U
Acenaphthylene	10 U	10 U	10 U	10 U	10 U	11 U	12 U
2,6-Dinitrotoluene	10 U	10 U	10 U	10 U	10 U	11 U	12 U
3-Nitroaniline	25 U	25 U	25 U	25 U	25 U	28 U	29 U

**NOTES:**

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

TABLE 5-6 (CONTINUED)

SEMI-VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER SAMPLES  
 SITE 12  
 EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 AUGUST, 1995

SAMPLE NUMBER MATRIX UNITS	LC12-GW106 WATER UG/L	LC12-GW107 WATER UG/L	LC12-GW108 WATER UG/L	LC12-GW109 WATER UG/L	LC12-GW110 WATER UG/L	LC12-GW-FB WATER UG/L	LC12-GW-RB WATER UG/L
Acenaphthene	10 U	10 U	10 U	10 U	10 U	11 U	12 U
2,4-Dinitrophenol	25 U	25 U	25 U	25 U	25 U	28 U	29 U
4-Nitrophenol	25 U	25 U	25 U	25 U	25 U	28 U	29 U
Dibenzofuran	10 U	10 U	10 U	10 U	10 U	11 U	12 U
2,4-Dinitrotoluene	10 U	10 U	10 U	10 U	10 U	11 U	12 U
Diethylphthalate	10 U	10 U	10 U	10 U	10 U	11 U	12 U
4-Chlorophenylphenyl Ether	10 U	10 U	10 U	10 U	10 U	11 U	12 U
Fluorene	10 U	10 U	10 U	10 U	10 U	11 U	12 U
4-Nitroaniline	25 U	25 U	25 U	25 U	25 U	28 U	29 U
4,6-Dinitro-2-Methylphenol	25 U	25 U	25 U	25 U	25 U	28 U	29 U
N-nitrosodiphenylamine	10 U	10 U	10 U	10 U	10 U	11 U	12 U
4-Bromophenylphenyl Ether	10 U	10 U	10 U	10 U	10 U	11 U	12 U
Hexachlorobenzene	10 U	10 U	10 U	10 U	10 U	11 U	12 U
Pentachlorophenol	25 U	25 U	25 U	25 U	25 U	28 U	29 U
Phenanthrene	10 U	10 U	10 U	10 U	10 U	11 U	12 U
Anthracene	10 U	10 U	10 U	10 U	10 U	11 U	12 U
Carbazole	10 U	10 UJ	10 U	10 U	10 U	11 U	12 U
Di-n-Butyl Phthalate	10 U	10 U	10 U	10 U	10 U	11 U	12 U
Fluoranthene	10 U	10 U	10 U	10 U	10 U	11 U	12 U
Pyrene	10 U	10 U	10 U	10 U	10 U	11 U	12 U
Butyl Benzyl Phthalate	10 U	10 U	10 U	10 U	10 U	11 U	12 U
3,3'-Dichlorobenzidine	10 U	10 U	10 U	10 U	10 U	11 U	12 U
Benzo(a)anthracene	10 U	10 U	10 U	10 U	10 U	11 U	12 U
Chrysene	10 U	10 U	10 U	10 U	10 U	11 U	12 U
bis(2-Ethylhexyl)Phthalate	10 U	10 U	10 U	10 U	0.9 J	11 U	12 U
Di-n-Octylphthalate	10 UJ	10 U	10 U	10 U	10 U	11 U	12 U
Benzo(b)fluoranthene	10 UJ	10 U	10 U	10 U	10 U	11 U	12 U
Benzo(k)fluoranthene	10 UJ	10 U	10 U	10 U	10 U	11 U	12 U
Benzo(a)Pyrene	10 UJ	10 U	10 U	10 U	10 U	11 U	12 U
Indeno(1,2,3-cd)pyrene	10 UJ	10 U	10 U	10 U	10 U	11 U	12 U
Dibenzo(a,h)anthracene	10 UJ	10 U	10 U	10 U	10 U	11 U	12 U
Benzo(g,h,i)Perylene	10 UJ	10 U	10 U	10 U	10 U	11 U	12 U

## NOTES:

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

TABLE 5-7

PESTICIDES AND PCBs DETECTED IN GROUNDWATER SAMPLES  
 SITE 12  
 EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 AUGUST, 1995

SAMPLE NUMBER MATRIX UNITS	LC12-GW-RB WATER UG/L	LC12-GW101 WATER UG/L	LC12-GW102 WATER UG/L	LC12-GW103 WATER UG/L	GW103MS WATER UG/L	GW103MSD WATER UG/L	LC12-GW104 WATER UG/L
alpha-BHC	0.050 U	0.050 UJ	0.050 UJ	0.050 UJ	0.10 U	0.10 U	0.050 UL
beta-BHC	0.050 U	0.050 UJ	0.050 UJ	0.050 UJ	0.10 U	0.10 U	0.050 UL
delta-BHC	0.050 U	0.050 UJ	0.050 UJ	0.050 UJ	0.10 U	0.10 U	0.050 UL
gamma-BHC (Lindane)	0.050 U	0.050 UJ	0.050 UJ	0.050 UJ	1.0	0.81	0.050 UL
Heptachlor	0.050 U	0.050 UJ	0.050 UJ	0.050 UJ	0.96	0.76	0.050 UL
Aldrin	0.050 U	0.050 UJ	0.015 J	0.050 UJ	1.0	0.80	0.050 UL
Heptachlor Epoxide	0.050 U	0.050 UJ	0.050 UJ	0.050 UJ	0.10 U	0.10 U	0.050 UL
Endosulfan I	0.050 U	0.050 UJ	0.050 UJ	0.050 UJ	0.10 U	0.10 U	0.050 UL
Dieldrin	0.10 U	0.10 UJ	0.10 UJ	0.10 UJ	2.1	1.7	0.10 UL
4,4'-DDE	0.10 U	0.10 UJ	0.10 UJ	0.10 UJ	0.20 U	0.20 U	0.10 UL
Endrin	0.10 U	0.10 UJ	0.10 UJ	0.10 UJ	2.1 P	1.6	0.10 UL
Endosulfan II	0.10 U	0.10 UJ	0.10 UJ	0.10 UJ	0.20 U	0.20 U	0.10 UL
4,4'-DDD	0.10 U	0.10 UJ	0.10 UJ	0.10 UJ	0.032 JP	0.023 JP	0.10 UL
Endosulfan Sulfate	0.10 U	0.10 UJ	0.10 UJ	0.10 UJ	0.20 U	0.20 U	0.10 UL
4,4'-DDT	0.10 U	0.10 UJ	0.10 UJ	0.10 UJ	2.0	1.5	0.10 UL
Methoxychlor	0.50 U	0.50 UJ	0.50 UJ	0.50 UJ	1.0 U	1.0 U	0.50 UL
Endrin Ketone	0.10 U	0.10 UJ	0.10 UJ	0.10 UJ	0.080 J	0.061 J	0.10 UL
Endrin Aldehyde	0.10 U	0.10 UJ	0.10 UJ	0.10 UJ	0.052 J	0.034 J	0.10 UL
alpha-Chlordane	0.050 U	0.050 UJ	0.050 UJ	0.050 UJ	0.10 U	0.10 U	0.069L
gamma-Chlordane	0.050 U	0.050 UJ	0.050 UJ	0.050 UJ	0.10 U	0.10 U	0.050L
Toxaphene	5.0 U	5.0 UJ	5.0 UJ	5.0 UJ	10 U	10 U	5.0 UL
Aroclor 1016	1.0 U	1.0 UJ	1.0 UJ	1.0 UJ	2.0 U	2.0 U	1.0 UL
Aroclor 1221	2.0 U	2.0 UJ	2.0 UJ	2.0 UJ	4.0 U	4.0 U	2.0 UL
Aroclor 1232	1.0 U	1.0 UJ	1.0 UJ	1.0 UJ	2.0 U	2.0 U	1.0 UL
Aroclor 1242	1.0 U	1.0 UJ	1.0 UJ	1.0 UJ	2.0 U	2.0 U	1.0 UL
Aroclor-1248	1.0 U	1.0 UJ	1.0 UJ	1.0 UJ	2.0 U	2.0 U	1.0 UL
Aroclor-1254	1.0 U	1.0 UJ	1.0 UJ	1.0 UJ	2.0 U	2.0 U	1.0 UL
Aroclor-1260	1.0 U	1.0 UJ	1.0 UJ	1.0 UJ	2.0 U	2.0 U	1.0 UL

## NOTES:

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

L indicates results biased low

TABLE 5-7 (CONTINUED)

PESTICIDES AND PCBs DETECTED IN GROUNDWATER SAMPLES  
 SITE 12  
 EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 AUGUST, 1995

SAMPLE NUMBER MATRIX UNITS	LC12-GW105 WATER UG/L	LC12-GW106 WATER UG/L	LC12-GW107 WATER UG/L	LC12-GW108 WATER UG/L	LC12-GW109 WATER UG/L	LC12-GW110 WATER UG/L
alpha-BHC	0.050 UJ	0.050 UJ	0.050UL	0.050 UL	0.050 UJ	0.050 UL
beta-BHC	0.050 UJ	0.050 UJ	0.050 UL	0.050 UL	0.050 UJ	0.050 UL
delta-BHC	0.050 UJ	0.050 UJ	0.050 UL	0.050 UL	0.050 UJ	0.050 UL
gamma-BHC (Lindane)	0.050 UJ	0.050 UJ	0.050 UL	0.050 UL	0.050 UJ	0.050 UL
Heptachlor	0.050 UJ	0.050 UJ	0.050 UL	0.050 UL	0.050 UJ	0.050 UL
Aldrin	0.050 UJ	0.050 UJ	0.050 UL	0.050 UL	0.050 UJ	0.050 UL
Heptachlor Epoxide	0.038 J	0.050 UJ	0.050 UL	0.050 UL	0.050 UJ	0.050 UL
Endosulfan I	0.050 UJ	0.050 UJ	0.050 UL	0.050 UL	0.050 UJ	0.050 UL
Dieldrin	0.10 UJ	0.10 UJ	0.10 UL	0.10 UL	0.10 UJ	0.10 UL
4,4'-DDE	0.10 UJ	0.10 UJ	0.10 UL	0.10 UL	0.10 UJ	0.10 UL
Endrin	0.10 UJ	0.10 UJ	0.10 UL	0.10 UL	0.10 UJ	0.10 UL
Endosulfan II	0.10 UJ	0.10 UJ	0.10 UL	0.10 UL	0.10 UJ	0.10 UL
4,4'-DDD	0.10 UJ	0.10 UJ	0.10 UL	0.10 UL	0.10 UJ	0.10 UL
Endosulfan Sulfate	0.10 UJ	0.10 UJ	0.10 UL	0.10 UL	0.10 UJ	0.10 UL
4,4'-DDT	0.10 UJ	0.10 UJ	0.10 UL	0.10 UL	0.10 UJ	0.10 UL
Methoxychlor	0.50 UJ	0.50 UJ	0.50 UL	0.50 UL	0.50 UJ	0.50 UL
Endrin Ketone	0.10 UJ	0.10 UJ	0.10 UL	0.10 UL	0.10 UJ	0.10 UL
Endrin Aldehyde	0.10 UJ	0.10 UJ	0.10 UL	0.10 UL	0.10 UJ	0.10 UL
alpha-Chlordane	0.081J	0.050 UJ	0.050 UL	0.015 L	0.050 UJ	0.050 UL
gamma-Chlordane	0.046 J	0.050 UJ	0.050 UL	0.050 UL	0.050 UJ	0.050 UL
Toxaphene	5.0 UJ	5.0 UJ	5.0 UL	5.0 UL	5.0 UJ	5.0 UL
Aroclor 1016	1.0 UJ	1.0 UJ	1.0 UL	1.0 UL	1.0 UJ	1.0 UL
Aroclor 1221	2.0 UJ	2.0 UJ	2.0 UL	2.0 UL	2.0 UJ	2.0 UL
Aroclor 1232	1.0 UJ	1.0 UJ	1.0 UL	1.0 UL	1.0 UJ	1.0 UL
Aroclor 1242	1.0 UJ	1.0 UJ	1.0 UL	1.0 UL	1.0 UJ	1.0 UL
Aroclor-1248	1.0 UJ	1.0 UJ	1.0 UL	1.0 UL	1.0 UJ	1.0 UL
Aroclor-1254	1.0 UJ	1.0 UJ	1.0 UL	1.0 UL	1.0 UJ	1.0 UL
Aroclor-1260	1.0 UJ	1.0 UJ	1.0 UL	1.0 UL	1.0 UJ	1.0 UL

## NOTES:

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

L indicates results biased low

TABLE 5-8

INORGANIC COMPOUNDS DETECTED IN GROUNDWATER SAMPLES  
 SITE 12  
 EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 SEPTEMBER, 1995

SAMPLE NUMBER MATRIX UNITS	LC12-GW-RB WATER UG/L	LC12-GW-RBT WATER UG/L	LC12-GW101 WATER UG/L	LC12-GW101T WATER UG/L	LC12-GW102 WATER UG/L	LC12-GW102T WATER UG/L	LC12-GW103 WATER UG/L	LC12-GW103T WATER UG/L
Aluminum	15.70 B	43.20 B	21.80 B	52500.00	17.40 B	96700.00	52.90 B	23800.00
Antimony	11.50 U	11.50 U	11.50 U	11.50 U	11.50 U	11.50 U	11.50 U	11.50 U
Arsenic	2.60 U	2.60 U	2.60 U	65.30	2.60 U	125.00	2.60 U	27.90
Barium	0.70 U	0.70 U	23.70 B	163.00 B	49.10 B	210.00	41.30 B	93.30 B
Beryllium	0.30 U	0.30 U	0.30 U	1.80 B	0.30 U	2.50 U	0.30 U	1.10 U
Cadmium	1.20 U	1.20 U	1.20 U	1.20 U	1.20 U	2.70 U	1.20 U	1.20 U
Calcium	253.00 B	28.80 U	13100.00	14800.00	16800.00	22300.00	10200.00	12000.00
Chromium	1.40 U	1.60 B	1.40 U	65.50	1.40 U	107.00	2.80 B	27.80
Cobalt	2.60 U	2.60 U	2.60 U	19.30 B	2.70 B	23.80 B	5.40 B	13.90 B
Copper	4.00 U	4.00 U	4.00 U	49.70	4.00 U	47.10	4.00 U	11.10 B
Iron	100.00 U	100.00 U	100.00 U	78600.00	100.00 U	124000.00	3680.00	34700.00
Lead	1.50 U	1.50 U	1.50 U	33.30	1.50 U	43.10	1.50 U	15.80
Magnesium	37.30	19.20 U	10700.00	15700.00	4410.00 B	8960.00	4620.00 B	6990.00
Manganese	1.30 U	0.98 U	112.00	349.00	736.00	1270.00	172.00	246.00
Mercury	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U	0.24 J	0.20 U	0.21 J
Nickel	3.90 U	3.90 U	6.00 B	36.00 B	3.90 U	26.80 B	3.90 U	16.60 B
Potassium	82.10 U	82.10 U	2270.00 B	5180.00	2770.00 B	7190.00	2110.00 B	3770.00 B
Selenium	4.30 U	4.30 U	4.30 U	4.30 U	4.30 U	4.30 U	4.30 U	4.30 U
Silver	1.90 U	1.90 U	1.90 U	1.90 U	1.90 U	1.90 U	1.90 U	1.90 U
Sodium	167.00 U	72.20 U	16900.00	19100.00	11600.00	13400.00	19600.00	21600.00
Thallium	4.10 U	4.10 U	4.10 U	4.10 U	4.10 U	4.10 U	4.10 U	4.10 U
Vanadium	2.10 U	2.10 U	2.10 U	103.00	2.10 U	188.00	2.10 U	44.50 B
Zinc	26.00 J	4.80 U	10.90 U	76.80 U	31.40 J	91.00 J	137.00 J	63.50 J
Cyanide	NA	5.00 U	NA	6.00	NA	5.00 U	NA	5.00 U

**NOTES:**

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

L indicates results biased low

NA indicates Not Analyzed

TABLE 5-8 (CONTINUED)

INORGANIC COMPOUNDS DETECTED IN GROUNDWATER SAMPLES  
 SITE 12  
 EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 SEPTEMBER, 1995

SAMPLE NUMBER MATRIX UNITS	LC12-GW104 WATER UG/L	LC12-GW104T WATER UG/L	LC12-GW105 WATER UG/L	LC12-GW105T WATER UG/L	LC12-GW106 WATER UG/L	LC12-GW106T WATER UG/L	LC12-GW107 WATER UG/L
Aluminum	10.30 U	91200.00	117.00 B	27200.00	24.70 B	15200.00	17.10 B
Antimony	11.50 U	11.50 U	11.50 U	11.50 U	11.50 U	11.50 U	11.50 U
Arsenic	4.30 B	92.50	2.60 U	25.30	2.60 U	17.70	13.00 U
Barium	55.00 B	262.00	54.80 B	112.00 B	45.60 B	78.70 B	45.20 B
Beryllium	0.30 U	2.80 U	0.30 U	1.20 U	0.38 U	0.96 U	0.30 U
Cadmium	1.20 U	2.60 U	1.20 U	1.30 U	1.20 U	1.20 U	1.40 U
Calcium	19900.00	32300.00	7400.00	7460.00	9070.00	9940.00	12100.00
Chromium	1.40 U	99.10	1.40 U	41.40	1.40 U	28.00	1.60 B
Cobalt	3.10 B	17.50 B	2.60 U	9.00 B	9.40 B	13.00 B	3.60 B
Copper	4.00 U	69.00	4.00 U	14.90 B	4.00 U	11.20 B	4.00 U
Iron	1220.00	111000.00	275.00	32300.00	919.00	24200.00	1040.00
Lead	43.50	88.10	1.50 U	11.80	1.50 U	11.10	7.50 U
Magnesium	6280.00	12000.00	9100.00	11700.00	6080.00	7950.00	6810.00
Manganese	168.00	384.00	166.00	232.00	566.00	672.00	439.00
Mercury	0.20 U	1.30 JL	0.20 U	0.24 J	0.20 U	0.20 U	0.20 U
Nickel	3.90 U	37.20 B	3.90 B	18.20 B	3.90 U	11.80 B	5.00 B
Potassium	2620.00 B	7210.00	2230.00 B	4520.00 B	3030.00 B	4680.00 B	2160.00 B
Selenium	4.30 U	4.30 U	4.30 U	4.30 U	4.30 U	4.30 U	21.50 U
Silver	1.90 U	1.90 U	1.90 U	1.90 U	1.90 U	1.90 U	1.90 U
Sodium	16700.00	20000.00	35300.00	34900.00	26300.00	27200.00	16300.00
Thallium	4.10 U	4.10 U	4.10 U	4.10 U	4.10 U	4.10 U	20.50 U
Vanadium	2.10 U	148.00	2.10 U	65.30	2.10 U	41.60 B	2.10 U
Zinc	32.10 J	234.00 J	35.70 J	67.30 J	28.10 J	51.60 J	35.30 J
Cyanide	NA	5.00 U	NA	5.00 U	NA	5.00 U	NA

**NOTES:**

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

L indicates results biased low

NA indicates Not Analyzed

TABLE 5-8 (CONTINUED)

INORGANIC COMPOUNDS DETECTED IN GROUNDWATER SAMPLES  
 SITE 12  
 EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 SEPTEMBER, 1995

SAMPLE NUMBER MATRIX UNITS	LC12-GW107T WATER UG/L	LC12-GW108 WATER UG/L	LC12-GW108T WATER UG/L	LC12-GW109 WATER UG/L	LC12-GW109T WATER UG/L	LC12-GW110 WATER UG/L	LC12-GW110T WATER UG/L
Aluminum	66400.00	28.20 B	78700.00	11.60 B	80400.00	21.1 B	85600.00
Antimony	11.50 U	11.50 U	11.50 U	11.50 U	11.50 U	11.5 U	11.5 U
Arsenic	65.00	2.60 U	67.50	2.60 U	69.10	2.6 U	88.3
Barium	335.00	49.10 B	478.00	78.80 B	285.00	48.2 B	269.00
Beryllium	4.40 B	0.30 U	4.90 B	0.30 U	5.10	0.30 U	3.7 B
Cadmium	2.50 U	5.90U	16.60	1.20 U	1.90 U	8.1	12.4
Calcium	20100.00	8520.00	14600.00	9930.00	14000.00	8470.00	10600.00
Chromium	114.00	1.60 B	124.00	2.20 B	153.00	1.4 U	138
Cobalt	34.20 B	6.70 B	40.00 B	7.60 B	50.30	7.2 B	32.8 B
Copper	46.20	4.00 U	58.70	4.00 U	58.30	4.0 U	47
Iron	111000.00	362.00	128000.00	4220.00	129000.00	426.00	140000.00
Lead	49.00	1.50 U	44.60	1.50 U	43.60	1.5U	41.8
Magnesium	15700.00	8040.00	17500.00	4520.00 B	15000.00	7700.00	15600.00
Manganese	1030.00	396.00	959.00	539.00	1020.00	390.00	750
Mercury	0.21 J	0.20 U	0.25 J	0.20 U	0.20 U	0.20 U	0.23J
Nickel	53.50	12.20 B	65.30	6.50 B	75.40	10.9 B	57.1
Potassium	8100.00	2620.00 B	8230.00	2740.00 B	10300.00	2880 B	8290.00
Selenium	4.30 U	4.30 U	4.30 U	4.30 U	4.30 U	4.3 U	4.3 U
Silver	1.90 U	1.90 U	1.90 U	1.90 U	1.90 U	1.9 U	1.9 U
Sodium	17200.00	23700.00	23300.00	12900.00	11800.00	23000.00	22300.00
Thallium	4.10 U	4.10 U	4.10 U	4.10 U	4.10 U	4.10 U	4.1 U
Vanadium	261.00	2.10 U	249.00	2.50 B	282.00	2.1 U	248.00
Zinc	195.00 J	36.40 J	190.00 J	45.20 J	262.00 J	33.1	158 J
Cyanide	5.00 U	NA	5.00 U	NA	5.00 U	NA	5.00 U

**NOTES:**

UG/L. indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

L indicates results biased low

NA indicates Not Analyzed

Total cadmium was detected in one sample, LC12-GW108, at 16.6 µg/l. Dissolved cadmium was detected in LC12-GW110, the duplicate sample of LC12-GW108, at 8.1 µg/l, though not in LC12-GW108 itself.

Total calcium was detected in all nine groundwater samples at levels ranging from 7,460 µg/l in LC12-GW105 to 32,300 µg/l in LC12-GW104. Dissolved calcium was detected in all nine groundwater samples at levels ranging from 7,400 µg/l in LC12-GW105 to 19,900 µg/l in LC12-GW104.

Total chromium was detected in all nine groundwater samples at levels ranging from 27.8 µg/l in LC12-GW103 to 153 µg/l in LC12-GW109.

Total cobalt was detected in one of the nine groundwater samples, LC12-GW109, at 50.3 µg/l.

Total copper was detected in six of the nine groundwater samples at levels ranging from 46.2 µg/l in LC12-GW107 to 69 µg/l in LC12-GW104.

Total iron was detected in all nine groundwater samples at levels ranging from 24,200 µg/l in LC12-GW106 to 129,000 µg/l in LC12-GW109. Dissolved iron was detected in seven of the nine groundwater samples at levels ranging from 275 µg/l in LC12-GW105 to 4,220 µg/l in LC12-GW109.

Total lead was detected in all nine groundwater samples at levels ranging from 11.1 µg/l in LC12-GW106 to 88.1 µg/l in LC12-GW104. Dissolved lead was detected in one sample, LC12-GW104, at 43.5 µg/l.

Total magnesium was detected in all nine groundwater samples at levels ranging from 6,990 µg/l in LC12-GW103 to 17,500 µg/l in LC12-GW108. Dissolved magnesium was detected in six of the nine groundwater samples at levels ranging from 6,080 µg/l in LC12-GW106 to 10,700 µg/l in LC12-GW101.

Total manganese was detected in all nine groundwater samples at levels ranging from 232 µg/l in LC12-GW105 to 1,270 µg/l in LC12-GW102. Dissolved manganese was detected in all nine groundwater samples at levels ranging from 112 µg/l in LC12-GW101 to 736 µg/l in LC12-GW102.

Total mercury was detected in six of the nine groundwater samples at levels ranging from 0.21 µg/l (J) in LC12-GW103 and LC12-GW107, to 1.3 µg/l (JL) in LC12-GW104.

Total nickel was detected in three of the nine groundwater samples at levels ranging from 53.5 µg/l in LC12-GW107 to 75.4 µg/l in LC12-GW109.

Total potassium was detected in six of the nine groundwater samples at levels ranging from 5,180 µg/l in LC12-GW101 to 10,300 µg/l in LC12-GW109.

Total sodium was detected in all nine groundwater samples at levels ranging from 11,800 µg/l in LC12-GW109 to 34,900 µg/l in LC12-GW105. Dissolved sodium was detected in all nine groundwater samples at levels ranging from 11,600 µg/l in LC12-GW102 to 35,300 µg/l in LC12-GW105.



Total vanadium was detected in seven of the nine groundwater samples at levels ranging from 65.3 µg/l in LC12-GW105 to 282 µg/l in LC12-GW109.

Total zinc was detected in eight of the nine groundwater samples at levels ranging from 51.6 µg/l (J) in LC12-GW106 to 262 µg/l (J) in LC12-GW109. Dissolved zinc was detected in eight of the nine groundwater samples at levels ranging from 28.1 µg/l (J) in LC12-GW106 to 137 µg/l (J) in LC12-GW103.

Cyanide was detected in one groundwater sample, LC12-GW101, at 6 µg/l.

## **Anions**

A summary of **anions** detected in groundwater samples is presented in **Table 5-9**.

## **Surface Water**

Four surface water samples were collected from the drainage canal which is located along the west side of Site 12. Specifically, these samples were collected north of Site 12, between the site and Lake Bradford. These samples were analyzed for VOCs and TAL metals.

## **VOCs**

One VOC, acetone, was detected in one of the four surface water samples. **Table 5-10** presents a summary of VOCs detected in surface water, and associated quality control samples, at Site 12. Acetone, a common laboratory contaminant, was detected in LC12-SW-107 at 13 µg/l (J), as well as in LC12-SW-109, the duplicate sample of LC12-SW-105, at 15 µg/l (J), though not in LC12-SW-105 itself.

## **TAL Metals**

TAL metals were detected at all four sampling locations. **Table 5-11** presents a summary of TAL metals detected in surface water, and associated quality control samples, at Site 12.

The following metals were detected in the four surface water samples, though each compound was not detected in each sample: aluminum, barium, cadmium, calcium, iron, manganese, sodium, and zinc.

Aluminum was detected in LC12-SW-105 and LC12-SW-107 at 274 µg/l and 293 µg/l, respectively. Barium was detected in LC12-SW-105 at 10 µg/l. Cadmium was detected in LC12-SW-108 at 1.7 µg/l (K). Calcium was detected in LC12-SW-107 and LC12-SW-108 at 5,570 µg/l and 8,870 µg/l, respectively. Iron was detected in all four surface water samples at levels ranging from 951 µg/l in LC12-SW-108 to 1,440 µg/l in LC12-SW-107. Manganese was detected in all four surface water samples at levels ranging from 103 µg/l in LC12-SW-106 to 208 µg/l in LC12-SW-108. Sodium was detected in LC12-SW-107 and LC12-SW-108 at 5,690 µg/l and 11,400 µg/l, respectively. Zinc was detected in three of the four surface water samples at levels ranging from 27.4 µg/l (J) in LC12-SW-107 to 34.4 µg/l (J) in LC12-SW-105.

TABLE 5-9

**ANIONS DETECTED IN GROUNDWATER SAMPLES**  
**SITE 12**  
**EXCHANGE LAUNDRY WASTE DISPOSAL AREA**  
**NAVAL AMPHIBIOUS BASE LITTLE CREEK**  
**VIRGINIA BEACH, VIRGINIA**  
**SEPTEMBER, 1995**

SAMPLE NUMBER MATRIX UNITS	LC12-GW-RB 09/19/95 MG/L	LC12-GW101 09/18/95 MG/L	LC12-GW102 09/18/95 MG/L	LC12-GW103 09/19/95 MG/L	LC12-GW104 09/19/95 MG/L	LC12-GW105 09/18/95 MG/L
FLUORIDE	1.000 U	1.000 U	1.000 U	1.000 U	1.000 U	1.000 U
CHLORIDE	1.000 U	31.000 U	40.000	33.000	20.000	34.000
NITRATE	.500 U	2.900	.500 U	.500 U	.500 U	3.000
PHOSPHATE	1.000 U	1.000 U	1.000 U	1.000 U	1.000 U	1.000 U
SULFATE (SO <sub>4</sub> <sup>2-</sup> )	1.000 U	57.000	45.000	47.000	35.000	80.000

**NOTES:**

MG/L indicates milligrams per liter

U indicates compound not detected above detection limit

TABLE 5-9 (CONTINUED)

ANIONS DETECTED IN GROUNDWATER SAMPLES  
 SITE 12  
 EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 SEPTEMBER, 1995

SAMPLE NUMBER MATRIX UNITS	LC12-GW106 09/18/95 MG/L	LC12-GW107 09/19/95 MG/L	LC12-GW108 09/19/95 MG/L	LC12-GW110 * 09/19/95 MG/L	LC12-GW109 09/19/95 MG/L
FLUORIDE	1.000 U	1.000 U	1.000 U	1.000 U	1.000 U
CHLORIDE	40.000	27.000	35.000	34.000	16.000
NITRATE	.500 U	.700	1.100	1.200	.600
PHOSPHATE	1.000 U	1.000 U	1.000 U	1.000 U	1.000 U
SULFATE (SO42-)	37.000	44.000	46.000	46.000	36.000

## NOTES:

MG/L indicates milligrams per liter

U indicates compound not detected above detection limit

\* indicates duplicate sample of LC12-GW108.

TABLE 5-10

VOLATILE ORGANIC COMPOUNDS DETECTED IN SURFACE WATER SAMPLES  
 SITE 12  
 EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 SEPTEMBER, 1995

SAMPLE NUMBER MATRIX UNITS	LC12SW105 WATER UG/L	LC12SW106 WATER UG/L	LC12SW107 WATER UG/L	LC12SW108 WATER UG/L	LC12SW108MS WATER UG/L	LC12SW108MSD WATER UG/L	LC12SW109 WATER UG/L
Methyl chloride	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Methyl bromide	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Vinyl Chloride	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Chloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Methylene chloride	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Acetone	10 U	10 UJ	13J	10 UJ	18	19	15J
Carbon disulfide	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1-Dichloroethene	10 U	10 U	10 U	10 U	39	42	10 U
1,1-Dichloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,2-dichloroethene (Total)	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Chloroform	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,2-Dichloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Methyl ethyl ketone	10 U	10 UJ	10 UJ	10 UJ	10 U	10 U	10 UJ
1,1,1-Trichloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Carbon tetrachloride	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Bromodichloromethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,2-Dichloropropane	10 U	10 U	10 U	10 U	10 U	10 U	10 U
cis-1,3-Dichloropropene	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Trichloroethene	10 U	10 U	10 U	10 U	39	41	10 U
Dibromochloromethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1,2-Trichloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Benzene	10 U	10 U	10 U	10 U	41	42	10 U
trans-1,3-Dichloropropene	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Bromoform	10 U	10 U	10 U	10 U	10 U	10 U	10 U
4-Methyl-2-Pentanone	10 U	10 U	10 U	10 U	10 U	10 U	10 U
2-Hexanone	10 U	10 UJ	10 U	10 UJ	10 U	10 U	10 U
Tetrachloroethene	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1,2,2-Tetrachloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Toluene	10 U	10 U	10 U	10 U	41	42	10 U
Chlorobenzene	10 U	10 U	10 U	10 U	41	43	10 U
Ethylbenzene	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Styrene	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Xylene (total)	10 U	10 U	10 U	10 U	10 U	10 U	10 U

**NOTES:**

UG/KG indicates micrograms per kilogram

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

TABLE 5-11

**INORGANIC COMPOUNDS DETECTED IN SURFACE WATER SAMPLES**  
**SITE 12**  
**EXCHANGE LAUNDRY WASTE DISPOSAL AREA**  
**NAVAL AMPHIBIOUS BASE LITTLE CREEK**  
**VIRGINIA BEACH, VIRGINIA**  
**SEPTEMBER, 1995**

SAMPLE NUMBER MATRIX UNITS	LC12-SW-105 WATER UG/L	LC12-SW-106 WATER UG/L	LC12-SW-107 WATER UG/L	LC12-SW-108 WATER UG/L	LC12-SW-109 WATER UG/L
Aluminum	274	153 B	293	189.00B	344
Antimony	8.4 UL	8.4 UL	8.4 U	8.40 U	8.4UL
Arsenic	2.4 B	1.8 B	1.8 B	2.60 U	1.5 U
Barium	10	8.1 B	10.4 B	19.10 B	9.6 B
Beryllium	0.30 U	0.30 U	0.30 U	0.73 B	0.30 U
Cadmium	1.3 U	1.3 U	1.3 U	1.70 K	1.3 U
Calcium	4,920 B	4,390 B	5,570	8,870	4,800 B
Chromium	1.8 U	2.8 B	2.6 B	1.80 U	1.8 U
Cobalt	3.1 U	3.1 U	3.1 U	3.10 U	3.1 U
Copper	5.4 B	2.7 U	3.3 B	4.10 B	4.3 B
Iron	1,220	1,080	1,440	951.00	1,290
Lead	1.5 U	1.5 U	1.7 B	1.50 UL	1.5 U
Magnesium	1,090 B	1,080 B	1,400 B	2,780 B	1,070 B
Manganese	188	103	155	208.00	120
Mercury	0.20 U	0.20 U	0.20 U	0.20 UL	0.20 U
Nickel	2.9 U	2.9 U	2.9 U	3.70 B	2.9 U
Potassium	2,170 B	2,150 B	2,380 B	2,830 B	2,090 B
Selenium	2.5 U	2.5 U	2.5 U	4.30 UL	2.5 U
Silver	1.8 U	1.8 U	1.8 U	1.80 U	1.8 U
Sodium	4,710 B	4,760 B	5,690	11,400	4,480 B
Thallium	3.6 U	3.6 U	3.6 U	4.10 U	3.6 U
Vanadium	1.7 U	1.7 B	1.7 B	1.70 U	1.7 U
Zinc	34.4J	28.4 J	27.4 J	18.20 B	33.4 J

**NOTES:**

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

K indicates results biased high

L indicates results biased low

B indicates compound detected in laboratory blank

## Sediments

Four sediment samples were collected at Site 12, each from the corresponding locations of the four surface water samples presented above. These samples were analyzed for VOCs and TAL metals.

### **VOCs**

**Table 5-12** presents a summary of VOCs detected in sediment, and associated quality control samples, at Site 12. Acetone, a common laboratory contaminant, was detected in LC12-SED-105 at 73  $\mu\text{g/l}$  (J). Chlorobenzene was detected in LC12-SED-107 at 2  $\mu\text{g/l}$  (J).

### **TAL Metals**

TAL metals were detected at all four sampling locations. **Table 5-13** presents a summary of TAL metals detected in sediment, and associated quality control samples, at Site 12.

The following metals were detected in the four sediment samples, though each compound was not detected in each sample: aluminum, arsenic, chromium, iron, lead, manganese, and zinc.

Aluminum was detected in all four sediment samples at levels ranging from 1,050 mg/kg in LC12-SED-105 to 3,260 mg/kg in LC12-SED-108. Arsenic was detected in LC12-SED-105 at 7.5 mg/kg. Chromium was detected in three of the four sediment samples at levels ranging from 3.7 mg/kg in LC12-SED-107 to 4.8 mg/kg in LC12-SED-108. Iron was detected in all four sediment samples at levels ranging from 1,450 mg/kg in LC12-SED-107 to 3,900 mg/kg in LC12-SED-108. Lead was detected in all four sediment samples at levels ranging from 3.8 mg/kg in LC12-SED-108 to 101 mg/kg LC12-SED-107. Manganese was detected in all four sediment samples at levels ranging from 8.4 mg/kg in LC12-SED-105 to 26.2 mg/kg in LC12-SED-108. Zinc was detected in all four sediment samples at levels ranging from 10.3 mg/kg in LC12-SED-108 to 21.4 mg/kg in LC12-SED-109, the duplicate sample of LC12-SED-105.

## **5.1.2 Site 13 - Public Works PCP Dip Tank and Wash Rack**

### Subsurface Soils

Thirteen subsurface soil samples were collected at varying depths from soil borings at Site 13. All thirteen samples were analyzed for VOCs and SVOCs, while three samples also were analyzed for pesticides and PCBs, and TAL metals.

### **VOCs**

Five VOCs, acetone, benzene, carbon disulfide, 1,1,1-trichloroethane, and toluene, were detected in several of the soil samples. **Table 5-14** contains a summary of VOCs detected in soil, and associated quality control samples, at Site 13.

TABLE 5-12

VOLATILE ORGANIC COMPOUNDS DETECTED IN SEDIMENT SAMPLES  
 SITE 12  
 EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 SEPTEMBER, 1995

SAMPLE NUMBER MATRIX UNITS	LC12SED105 SOIL UG/KG	LC12SED106 SOIL UG/KG	LC12SED107 SOIL UG/KG	LC12SED108 SOIL UG/KG	LC12SED109 SOIL UG/KG	LC12SEDFB1 WATER UG/L	LC12SEDRB1 WATER UG/L	TRIPBLANKSED WATER UG/L
Methyl chloride	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
Methyl bromide	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
Vinyl Chloride	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
Chloroethane	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
Methylene chloride	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
Acetone	73J	16 U	19 U	52 B	16 U	40J	22J	21J
Carbon disulfide	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
1,1-Dichloroethene	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
1,1-Dichloroethane	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
1,2-dichloroethene (Total)	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
Chloroform	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
1,2-Dichloroethane	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
Methyl ethyl ketone	17 U	16 U	19 U	13 U	16 U	10 UJ	10 UJ	10 UJ
1,1,1-Trichloroethane	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
Carbon tetrachloride	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
Bromodichloromethane	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
1,2-Dichloropropane	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
cis-1,3-Dichloropropene	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
Trichloroethene	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
Dibromochloromethane	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
1,1,2-Trichloroethane	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
Benzene	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
trans-1,3-Dichloropropene	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
Bromoform	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
4-Methyl-2-Pentanone	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
2-Hexanone	17 U	16 U	19 U	13 U	16 U	10 UJ	10 UJ	10 UJ
Tetrachloroethene	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
1,1,2,2-Tetrachloroethane	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
Toluene	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
Chlorobenzene	17 U	16 U	2 J	13 U	16 U	10 U	10 U	10 U
Ethylbenzene	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
Styrene	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U
Xylene (total)	17 U	16 U	19 U	13 U	16 U	10 U	10 U	10 U

## NOTES:

UG/KG indicates micrograms per kilogram

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

TABLE 5-13

INORGANIC COMPOUNDS DETECTED IN SEDIMENT SAMPLES  
 SITE 12  
 EXCHANGE LAUNDRY WASTE DISPOSAL AREA  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 SEPTEMBER, 1995

SAMPLE NUMBER MATRIX UNITS	LC12-SED-105 SOIL MG/KG	LC12-SED-106 SOIL MG/KG	LC12-SED-107 SOIL MG/KG	LC12-SED-108 SOIL MG/KG	LC12-SED-109 SOIL MG/KG	LC12-SED-FB-1 WATER UG/L	LC12-SED-RB-1 WATER UG/L
Aluminum	1050.00	2000.00	1720.00	3260.00	974.00	12.40 U	12.60 B
Antimony	2.90 UL	2.80 UL	3.00 UL	2.20 UL	2.80 UL	8.40 U	8.40 U
Arsenic	7.50	1.50 U	1.70 U	1.20 U	6.10	2.60 U	2.60 U
Barium	5.70 B	9.30 B	9.80 B	13.50 B	4.30 B	0.50 U	1.60 B
Beryllium	0.28 B	0.10 U	0.11 U	0.13 B	0.10 U	0.30 U	0.30 U
Cadmium	0.44 U	0.43 U	0.47 U	0.35 U	0.43 U	1.30 U	1.30 U
Calcium	263.00 B	283.00 B	582.00 B	290.00 B	219.00 B	41.50 B	62.30 B
Chromium	3.10 B	4.20	3.70	4.80	2.30 B	1.80 U	1.80 U
Cobalt	1.10 U	1.00 U	1.10 U	0.83 U	1.00 U	3.10 U	3.10 U
Copper	3.40 B	1.70 B	3.10 B	1.90 B	1.50 B	2.70 U	2.70 U
Iron	3430.00	1890.00	1450.00	3900.00	2780.00	4.30 B	29.80 B
Lead	7.30	6.90	101.00	3.80	4.70	1.50 UL	1.50 UL
Magnesium	124.00 B	191.00 B	180.00 B	239.00 B	104.00 B	9.00 B	47.30 B
Manganese	8.40	14.10	22.50	26.20	7.10	0.50 U	1.40 B
Mercury	0.17 U	0.16 U	0.18 U	0.13 U	0.16 U	0.20 UL	0.20 UL
Nickel	2.30 B	1.70 B	2.10 B	2.50 B	1.40 B	2.90 U	2.90 U
Potassium	89.60 B	112.00 B	121.00 B	162.00 B	81.50 B	75.30 U	101.00 B
Selenium	0.85 U	0.82 U	0.91 U	0.67 U	0.82 U	4.30 UL	4.30 UL
Silver	0.61 U	0.59 U	0.65 U	0.48 U	0.59 U	1.80 U	1.80 U
Sodium	77.30 B	69.10 B	61.60 B	61.60 B	57.30 B	130.00 B	161.00 B
Thallium	2.10 U	2.00 U	2.20 U	1.60 U	2.00 U	4.10 U	4.10 U
Vanadium	2.80 B	4.30 B	5.20 B	6.50 B	2.40 B	1.70 U	1.70 U
Zinc	18.90	15.50	20.50	10.30	21.40	5.70 B	4.30 B

**NOTES:**

UG/KG indicates micrograms per kilogram

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

L indicates results biased low



TABLE 5-14

VOLATILE ORGANIC COMPOUNDS DETECTED IN SOIL SAMPLES  
 SITE 13  
 PUBLIC WORKS PCP DIP TANK AND WASH RACK  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 AUGUST, 1995

SAMPLE NUMBER MATRIX UNITS	13SB-101-02 SOIL UG/KG	13SB-101-02 MS SOIL UG/KG	13SB-101-02 MSD SOIL UG/KG	13SB-102-02 SOIL UG/KG	13SB-103-02 SOIL UG/KG	13SB-104-02 SOIL UG/KG	13SB-104-03 SOIL UG/KG	13SB-105-02 SOIL UG/KG
Methyl chloride	13 U	12 U	12 U	12 U	12 U	12 U	12 U	12 U
Methyl bromide	13 U	12 U	12 U	12 U	12 U	12 U	12 U	12 U
Vinyl Chloride	13 U	12 U	12 U	12 U	12 U	12 U	12 U	12 U
Chloroethane	13 U	12 U	12 U	12 U	12 U	12 U	12 U	12 U
Methylene chloride	13 U	12 U	12 U	12 U	12 U	12 U	12 U	12 U
Acetone	13 U	12 U	12 U	51 U	29 J	14 U	12 U	12 U
Carbon disulfide	13 U	12 U	12 U	12 U	12 U	12 U	12 U	12 U
1,1-Dichloroethene	13 U	64	60	12 U	12 U	12 U	12 U	12 U
1,1-Dichloroethane	13 U	12 U	12 U	12 U	12 U	12 U	12 U	12 U
1,2-dichloroethene (Total)	13 U	12 U	12 U	12 U	12 U	12 U	12 U	12 U
Chloroform	13 U	12 U	12 U	12 U	12 U	12 U	12 U	12 U
1,2-Dichloroethane	13 U	12 U	12 U	12 U	12 U	12 U	12 U	12 U
Methyl ethyl ketone	13 U	12 U	12 U	12 U	12 U	12 U	12 U	12 U
1,1,1-Trichloroethane	13 U	12 U	12 U	12	12 U	12 U	12 U	12 U
Carbon tetrachloride	13 U	12 U	12 U	12 U	12 U	12 U	12 U	12 U
Bromodichloromethane	13 U	12 U	12 U	12 U	12 U	12 U	12 U	12 U
1,2-Dichloropropane	13 U	12 U	12 U	12 U	12 U	12 U	12 U	12 U
cis-1,3-Dichloropropene	13 U	12 U	12 U	12 U	12 U	12 U	12 U	12 U
Trichloroethene	13 U	60	63	12 U	12 U	12 U	12 U	12 U
Dibromochloromethane	13 U	12 U	12 U	12 U	12 U	12 U	12 U	12 U
1,1,2-Trichloroethane	13 U	12 U	12 U	12 U	12 U	12 U	12 U	12 U
Benzene	13 U	59	64	12 U	12 U	12 U	12 U	12 U
trans-1,3-Dichloropropene	13 U	12 U	12 U	12 U	12 U	12 U	12 U	12 U
Bromoform	13 U	12 U	12 U	12 U	12 U	12 U	12 U	12 U
4-Methyl-2-Pentanone	13 U	12 U	12 U	12 U	12 U	12 U	12 U	12 U
2-Hexanone	13 U	12 U	12 U	12 U	12 U	12 U	12 U	12 U
Tetrachloroethene	13 U	12 U	12 U	12 U	12 U	12 U	12 U	12 U
1,1,2,2-Tetrachloroethane	13 U	12 U	12 U	12 U	12 U	12 U	12 U	12 U
Toluene	13 U	60	63	12 U	4 J	12 U	12 U	3 J
Chlorobenzene	13 U	59	62	12 U	12 U	12 U	12 U	12 U
Ethylbenzene	13 U	12 U	12 U	12 U	12 U	12 U	12 U	12 U
Styrene	13 U	12 U	12 U	12 U	12 U	12 U	12 U	12 U
Xylene (total)	13 U	12 U	12 U	12 U	12 U	12 U	12 U	12 U

## NOTES:

UG/KG indicates micrograms per kilogram

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

TABLE 5-14 (CONTINUED)

VOLATILE ORGANIC COMPOUNDS DETECTED IN SOIL SAMPLES  
 SITE 13  
 PUBLIC WORKS PCP DIP TANK AND WASH RACK  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 AUGUST, 1995

SAMPLE NUMBER MATRIX UNITS	13SB-106-02 SOIL UG/KG	13SB-107-02 SOIL UG/KG	13SB-108-02 SOIL UG/KG	13SB-109-02 SOIL UG/KG	13SB-110-02 SOIL UG/KG	13SB-110-03 SOIL UG/KG	13SB-111-02 SOIL UG/KG	13SB-112-02 SOIL UG/KG
Methyl chloride	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U
Methyl bromide	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U
Vinyl Chloride	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U
Chloroethane	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U
Methylene chloride	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U
Acetone	18 U	65 U	38 U	34 U	52 U	45 U	44 U	48 U
Carbon disulfide	13 U	12 U	12 U	12 U	12 U	12 U	12 U	2 J
1,1-Dichloroethene	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U
1,1-Dichloroethane	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U
1,2-dichloroethene (Total)	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U
Chloroform	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U
1,2-Dichloroethane	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U
Methyl ethyl ketone	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U
1,1,1-Trichloroethane	13 U	12 U	12 U	12 U	12 U	12 U	12 U	21
Carbon tetrachloride	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U
Bromodichloromethane	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U
1,2-Dichloropropane	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U
cis-1,3-Dichloropropene	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U
Trichloroethene	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U
Dibromochloromethane	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U
1,1,2-Trichloroethane	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U
Benzene	13 U	12 U	12 U	12 U	12 U	12 U	12 U	5 J
trans-1,3-Dichloropropene	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U
Bromoform	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U
4-Methyl-2-Pentanone	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U
2-Hexanone	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U
Tetrachloroethene	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U
1,1,2,2-Tetrachloroethane	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U
Toluene	1 J	12 U	12 U	2 J	1 J	12 U	12 U	2 J
Chlorobenzene	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U
Ethylbenzene	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U
Styrene	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U
Xylene (total)	13 U	12 U	12 U	12 U	12 U	12 U	12 U	13 U

## NOTES:

UG/KG indicates micrograms per kilogram

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

TABLE 5-14 (CONTINUED)

VOLATILE ORGANIC COMPOUNDS DETECTED IN SOIL SAMPLES  
 SITE 13  
 PUBLIC WORKS PCP DIP TANK AND WASH RACK  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 AUGUST, 1995

SAMPLE NUMBER MATRIX UNITS	13SB-113-02 SOIL UG/KG	13SB-FB1 WATER UG/L	13SB-RB1 WATER UG/L	13SB-RB2 WATER UG/L	13SB-RB3 WATER UG/L	TRIP BLANK-4 WATER UG/L	TRIP BLANK-5 WATER UG/L	TRIP BLANK-6 WATER UG/L
Methyl chloride	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Methyl bromide	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Vinyl Chloride	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Chloroethane	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Methylene chloride	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Acetone	26 U	10 U	10 U	11	10 U	10 U	10 U	10 U
Carbon disulfide	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1-Dichloroethene	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1-Dichloroethane	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,2-dichloroethene (Total)	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Chloroform	11 U	10 U	10 U	2 J	2 J	10 U	10 U	10 U
1,2-Dichloroethane	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Methyl ethyl ketone	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1,1-Trichloroethane	9 J	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Carbon tetrachloride	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Bromodichloromethane	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,2-Dichloropropane	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
cis-1,3-Dichloropropene	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Trichloroethene	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Dibromochloromethane	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1,2-Trichloroethane	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Benzene	3 J	10 U	10 U	10 U	10 U	10 U	10 U	10 U
trans-1,3-Dichloropropene	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Bromoform	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
4-Methyl-2-Pentanone	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
2-Hexanone	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Tetrachloroethene	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1,2,2-Tetrachloroethane	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Toluene	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Chlorobenzene	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Ethylbenzene	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Styrene	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Xylene (total)	11 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U

## NOTES:

UG/KG indicates micrograms per kilogram

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

Acetone, a common laboratory contaminant, was detected in 13SB-103-02 at 29  $\mu\text{g/kg}$  (J). Carbon disulfide, also a common laboratory contaminant, was detected in 13SB-112-02 at 2  $\mu\text{g/kg}$  (J). Benzene was detected in 13SB-112-02 and 13SB-113-02 at 5  $\mu\text{g/kg}$  (J) and 3  $\mu\text{g/kg}$  (J), respectively. 1,1,1-trichloroethane was detected in 13SB-102-02, 13SB-112-02, and 13SB-113-02 at 12  $\mu\text{g/kg}$ , 21  $\mu\text{g/kg}$ , and 9  $\mu\text{g/kg}$  (J), respectively. Toluene was detected in six of the thirteen soil samples at levels ranging from 1  $\mu\text{g/kg}$  (J) in 13SB-106-02 and 13SB-110-02, to 4  $\mu\text{g/kg}$  (J) in 13SB-103-02.

## SVOCs

Five SVOCs, bis(2-ethylhexyl)phthalate, di-n-butyl phthalate, di-n-octylphthalate, 2-methylnaphthalene, and pentachlorophenol, were detected in several of the soil samples. **Table 5-15** presents a summary of SVOCs detected in soil, and associated quality control, samples at Site 13.

Bis(2-ethylhexyl)phthalate was detected in five of the thirteen soil samples at levels ranging from 45  $\mu\text{g/kg}$  (J) in 13SB-105-02 to 570  $\mu\text{g/kg}$  in 13SB-101-02. Bis(2-ethylhexyl)phthalate is a common laboratory contaminant.

Di-n-butyl phthalate was detected in four of the thirteen soil samples at levels ranging from 42  $\mu\text{g/kg}$  (J) in 13SB-112-02 to 58  $\mu\text{g/kg}$  (J) in 13SB-111-02.

Di-n-octylphthalate was detected in one sample, 13SB-101-02, at 56  $\mu\text{g/kg}$  (J).

2-methylnaphthalene was detected in one sample, 13SB-104-03, the duplicate sample of 13SB-104-02, at 69  $\mu\text{g/kg}$  (J), though was not detected in sample 13SB-104-02 itself.

Pentachlorophenol was detected in one sample, 13SB-102-02, at 2,700  $\mu\text{g/kg}$ .

## Pesticides and PCBs

**Table 5-16** presents a summary of pesticides and PCBs detected in soil, and associated quality control samples, at Site 13. Two pesticides, 4,4'-DDD and 4,4'-DDE, were detected in sample 13SB-101-02, at 1.5  $\mu\text{g/kg}$  (J) and 2.4  $\mu\text{g/kg}$  (J), respectively. No pesticides and PCBs were detected in the other two soil samples.

## TAL Metals

TAL metals were detected in all three soil samples analyzed. The following TAL metals were detected in the soil samples: aluminum, antimony, arsenic, barium, calcium, chromium, iron, lead, manganese, vanadium, and zinc. Not all compounds were detected in each soil sample. **Table 5-17** presents a summary of TAL metals detected in soil, and associated quality control, samples at Site 13.

Aluminum was detected in all three soil samples at levels ranging from 13,300 mg/kg in 13SB-102-02 to 18,400 mg/kg in 13SB-103-02.

Antimony was detected in one sample, 13SB-101-02, at 3.5 mg/kg (J).

TABLE 5-15

SEMI-VOLATILE ORGANIC COMPOUNDS DETECTED IN SOIL SAMPLES  
 SITE 13  
 PUBLIC WORKS PCP DIP TANK AND WASH RACK  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 AUGUST, 1995

SAMPLE NUMBER MATRIX UNITS	13SB-101-02 SOIL UG/KG	13SB-101-02 MS SOIL UG/KG	13SB-101-02 MSD SOIL UG/KG	13SB-102-02 SOIL UG/KG	13SB-102-02 MS SOIL UG/KG	13SB-102-02 MSD SOIL UG/KG	13SB-103-02 SOIL UG/KG
Phenol	390 U	1500	2100	400 U	2100	1900	380 U
bis(2-Chloroethyl) Ether	390 U	390 U	390 U	400 U	400 U	400 U	380 U
2-Chlorophenol	390 U	1600	2100	400 U	2000	1700	380 U
1,3-Dichlorobenzene	390 U	390 U	390 U	400 U	400 U	400 U	380 U
1,4-Dichlorobenzene	390 U	1200	1700	400 U	1600	1400	380 U
1,2-Dichlorobenzene	390 U	390 U	390 U	400 U	400 U	400 U	380 U
2-Methylphenol	390 U	390 U	390 U	400 U	400 U	400 U	380 U
bis(2-Chloroisopropyl)Ether	390 U	390 U	390 U	400 U	400 U	400 U	380 U
4-Methylphenol	390 U	390 U	390 U	400 U	400 U	400 U	380 U
N-Nitrosodipropylamine	390 U	690	980	400 U	1500	1100	380 U
Hexachloroethane	390 U	390 U	390 U	400 U	400 U	400 U	380 U
Nitrobenzene	390 U	390 U	390 U	400 U	400 U	400 U	380 U
Isophorone	390 U	390 U	390 U	400 U	400 U	400 U	380 U
2-Nitrophenol	390 U	390 U	390 U	400 U	400 U	400 U	380 U
2,4-Dimethylphenol	390 U	390 U	390 U	400 U	400 U	400 U	380 U
bis(2-Chloroethoxy)Methanol	390 U	390 U	390 U	400 U	400 U	400 U	380 U
2,4-Dichlorophenol	390 U	390 U	390 U	400 U	400 U	400 U	380 U
1,2,4-Trichlorobenzene	390 U	1300	1900	400 U	1700	1500	380 U
Naphthalene	390 U	390 U	390 U	400 U	400 U	400 U	380 U
4-Chloroaniline	390 U	390 U	390 U	400 U	400 U	400 U	380 U
Hexachlorobutadiene	390 U	390 U	390 U	400 U	400 U	400 U	380 U
4-Chloro-3-methylphenol	390 U	1400	2100	400 U	2200	1800	380 U
2-Methylnaphthalene	390 U	390 U	390 U	400 U	400 U	400 U	380 U
Hexachlorocyclopentadiene	390 U	390 U	390 U	400 U	400 U	400 U	380 U
2,4,6-Trichlorophenol	390 U	390 U	390 U	400 U	400 U	400 U	380 U
2,4,5-Trichlorophenol	950 U	950 U	950 U	960 U	960 U	960 U	930 U
2-Chloronaphthalene	390 U	390 U	390 U	400 U	400 U	400 U	380 U
2-Nitroaniline	950 U	950 U	950 U	960 U	960 U	960 U	930 U
Dimethylphthalate	390 U	390 U	390 U	400 U	400 U	400 U	380 U
Acenaphthylene	390 U	390 U	390 U	400 U	400 U	400 U	380 U
2,6-Dinitrotoluene	390 U	390 U	390 U	400 U	400 U	400 U	380 U
3-Nitroaniline	950 U	950 U	950 U	960 U	960 U	960 U	930 U

## NOTES:

UG/KG indicates micrograms per kilogram

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

TABLE 5-15 (CONTINUED)

SEMI-VOLATILE ORGANIC COMPOUNDS DETECTED IN SOIL SAMPLES  
 SITE 13  
 PUBLIC WORKS PCP DIP TANK AND WASH RACK  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 AUGUST, 1995

SAMPLE NUMBER MATRIX UNITS	13SB-101-02 SOIL UG/KG	13SB-101-02 MS SOIL UG/KG	13SB-101-02 MSD SOIL UG/KG	13SB-102-02 SOIL UG/KG	13SB-102-02 MS SOIL UG/KG	13SB-102-02 MSD SOIL UG/KG	13SB-103-02 SOIL UG/KG
Acenaphthene	390 U	1200	1800	400 U	1500	1400	380 U
2,4-Dinitrophenol	950 U	950 U	950 U	960 UJ	960 UJ	960 UJ	930 U
4-Nitrophenol	950 U	2200	3500	960 U	2400	2100	930 U
Dibenzofuran	390 U	390 U	390 U	400 U	400 U	400 U	380 U
2,4-Dinitrotoluene	390 U	1300	1900	400 U	1800	1600	380 U
Diethylphthalate	390 U	390 U	390 U	400 U	400 U	400 U	380 U
4-Chlorophenylphenyl Ether	390 U	390 U	390 U	400 U	400 U	400 U	380 U
Fluorene	390 U	390 U	390 U	400 U	400 U	400 U	380 U
4-Nitroaniline	950 U	950 U	950 U	960 U	960 U	960 U	930 U
4,6-Dinitro-2-Methylphenol	950 U	950 U	950 U	960 U	960 U	960 U	930 U
N-nitrosodiphenylamine	390 U	390 U	390 U	400 U	400 U	400 U	380 U
4-Bromophenylphenyl Ether	390 U	390 U	390 U	400 U	400 U	400 U	380 U
Hexachlorobenzene	390 U	390 U	390 U	400 U	400 U	400 U	380 U
Pentachlorophenol	950 U	3000J	5700J	2700	4800	4100	930 U
Phenanthrene	390 U	390 U	390 U	400 U	400 U	400 U	380 U
Anthracene	390 U	390 U	390 U	400 U	400 U	400 U	380 U
Carbazole	390 U	390 U	390 U	400 U	400 U	400 U	380 U
Di-n-Butyl Phthalate	390 U	390 U	390 U	43 J	43 J	43 J	380 U
Fluoranthene	390 U	390 U	390 U	400 U	400 U	400 U	380 U
Pyrene	390 U	1500	2400	400 U	1900	1700	380 U
Butyl Benzyl Phthalate	390 U	390 U	390 U	400 U	400 U	400 U	380 U
3,3'-Dichlorobenzidine	390 U	390 U	390 U	400 U	400 U	400 U	380 U
Benzo(a)anthracene	390 U	390 U	390 U	400 U	400 U	400 U	380 U
Chrysene	390 U	390 U	390 U	400 U	400 U	400 U	380 U
bis(2-Ethylhexyl)Phthalate	570	390 U	390 U	56 J	53 J	59 J	69 J
Di-n-Octylphthalate	56 J	390 U	390 U	400 U	400 U	400 U	380 U
Benzo(b)fluoranthene	390 U	390 U	390 U	400 U	400 U	400 U	380 U
Benzo(k)fluoranthene	390 U	390 U	390 U	400 U	400 U	400 U	380 U
Benzo(a)Pyrene	390 U	390 U	390 U	400 U	400 U	400 U	380 U
Indeno(1,2,3-cd)pyrene	390 U	390 U	390 U	400 U	400 U	400 U	380 U
Dibenzo(a,h)anthracene	390 U	390 U	390 U	400 U	400 U	400 U	380 U
Benzo(g,h,i)Perylene	390 U	390 U	390 U	400 U	400 U	64 J	380 U

## NOTES:

UG/KG indicates micrograms per kilogram

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

TABLE 5-15 (CONTINUED)

SEMI-VOLATILE ORGANIC COMPOUNDS DETECTED IN SOIL SAMPLES  
 SITE 13  
 PUBLIC WORKS PCP DIP TANK AND WASH RACK  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 AUGUST, 1995

SAMPLE NUMBER MATRIX UNITS	13SB-104-02 SOIL UG/KG	13SB-104-03 SOIL UG/KG	13SB-105-02 SOIL UG/KG	13SB-106-02 SOIL UG/KG	13SB-107-02 SOIL UG/KG	13SB-108-02 SOIL UG/KG	13SB-109-02 SOIL UG/KG
Phenol	380 U	390 U	380 U	380 U	380 U	390 U	390 U
bis(2-Chloroethyl) Ether	380 U	390 U	380 U	380 U	380 U	390 U	390 U
2-Chlorophenol	380 U	390 U	380 U	380 U	380 U	390 U	390 U
1,3-Dichlorobenzene	380 U	390 U	380 U	380 U	380 U	390 U	390 U
1,4-Dichlorobenzene	380 U	390 U	380 U	380 U	380 U	390 U	390 U
1,2-Dichlorobenzene	380 U	390 U	380 U	380 U	380 U	390 U	390 U
2-Methylphenol	380 U	390 U	380 U	380 U	380 U	390 U	390 U
bis(2-Chloroisopropyl) Ether	380 U	390 U	380 U	380 U	380 U	390 U	390 U
4-Methylphenol	380 U	390 U	380 U	380 U	380 U	390 U	390 U
N-Nitrosodipropylamine	380 U	390 U	380 U	380 U	380 U	390 U	390 U
Hexachloroethane	380 U	390 U	380 U	380 U	380 U	390 U	390 U
Nitrobenzene	380 U	390 U	380 U	380 U	380 U	390 U	390 U
Isophorone	380 U	390 U	380 U	380 U	380 U	390 U	390 U
2-Nitrophenol	380 U	390 U	380 U	380 U	380 U	390 U	390 U
2,4-Dimethylphenol	380 U	390 U	380 U	380 U	380 U	390 U	390 U
bis(2-Chloroethoxy)Methanol	380 U	390 U	380 U	380 U	380 U	390 U	390 U
2,4-Dichlorophenol	380 U	390 U	380 U	380 U	380 U	390 U	390 U
1,2,4-Trichlorobenzene	380 U	390 U	380 U	380 U	380 U	390 U	390 U
Naphthalene	380 U	390 U	380 U	380 U	380 U	390 U	390 U
4-Chloroaniline	380 U	390 U	380 U	380 U	380 U	390 U	390 U
Hexachlorobutadiene	380 U	390 U	380 U	380 U	380 U	390 U	390 U
4-Chloro-3-methylphenol	380 U	390 U	380 U	380 U	380 U	390 U	390 U
2-Methylnaphthalene	380 U	69 J	380 U	380 U	380 U	390 U	390 U
Hexachlorocyclopentadiene	380 U	390 U	380 U	380 U	380 U	390 U	390 U
2,4,6-Trichlorophenol	380 U	390 U	380 U	380 U	380 U	390 U	390 U
2,4,5-Trichlorophenol	930 U	950 U	920 U	920 U	920 U	950 U	950 U
2-Chloronaphthalene	380 U	390 U	380 U	380 U	380 U	390 U	390 U
2-Nitroaniline	930 U	950 U	920 U	920 U	920 U	950 U	950 U
Dimethylphthalate	380 U	390 U	380 U	380 U	380 U	390 U	390 U
Acenaphthylene	380 U	390 U	380 U	380 U	380 U	390 U	390 U
2,6-Dinitrotoluene	380 U	390 U	380 U	380 U	380 U	390 U	390 U
3-Nitroaniline	930 U	950 U	920 U	920 U	920 U	950 U	950 U

## NOTES:

UG/KG indicates micrograms per kilogram

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

TABLE 5-15 (CONTINUED)

SEMI-VOLATILE ORGANIC COMPOUNDS DETECTED IN SOIL SAMPLES  
 SITE 13  
 PUBLIC WORKS PCP DIP TANK AND WASH RACK  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 AUGUST, 1995

SAMPLE NUMBER MATRIX UNITS	13SB-104-02 SOIL UG/KG	13SB-104-03 SOIL UG/KG	13SB-105-02 SOIL UG/KG	13SB-106-02 SOIL UG/KG	13SB-107-02 SOIL UG/KG	13SB-108-02 SOIL UG/KG	13SB-109-02 SOIL UG/KG
Acenaphthene	380 U	390 U	380 U	380 U	380 U	390 U	390 U
2,4-Dinitrophenol	930 U	950 U	920 UJ	920 UJ	920 UJ	950 U	950 U
4-Nitrophenol	930 U	950 U	920 U	920 U	920 U	950 U	950 U
Dibenzofuran	380 U	390 U	380 U	380 U	380 U	390 U	390 U
2,4-Dinitrotoluene	380 U	390 U	380 U	380 U	380 U	390 U	390 U
Diethylphthalate	380 U	390 U	380 U	380 U	380 U	390 U	390 U
4-Chlorophenylphenyl Ether	380 U	390 U	380 U	380 U	380 U	390 U	390 U
Fluorene	380 U	390 U	380 U	380 U	380 U	390 U	390 U
4-Nitroaniline	930 U	950 U	920 U	920 U	920 U	950 U	950 U
4,6-Dinitro-2-Methylpheno	930 U	950 U	920 U	920 U	920 U	950 U	950 U
N-nitrosodiphenylamine	380 U	390 U	380 U	380 U	380 U	390 U	390 U
4-Bromophenylphenyl Ether	380 U	390 U	380 U	380 U	380 U	390 U	390 U
Hexachlorobenzene	380 U	390 U	380 U	380 U	380 U	390 U	390 U
Pentachlorophenol	930 U	380 J	920 U	920 U	920 U	950 U	950 U
Phenanthrene	380 U	390 U	380 U	380 U	380 U	390 U	390 U
Anthracene	380 U	390 U	380 U	380 U	380 U	390 U	390 U
Carbazole	380 U	390 U	380 U	380 U	380 U	390 U	390 U
Di-n-Butyl Phthalate	380 U	390 U	52 J	380 U	380 U	390 U	390 U
Fluoranthene	380 U	390 U	380 U	380 U	380 U	390 U	390 U
Pyrene	380 U	390 U	380 U	380 U	380 U	390 U	390 U
Butyl Benzyl Phthalate	380 U	390 U	380 U	380 U	380 U	390 U	390 U
3,3'-Dichlorobenzidine	380 U	390 U	380 U	380 U	380 U	390 U	390 U
Benzo(a)anthracene	380 U	390 U	380 U	380 U	380 U	390 U	390 U
Chrysene	380 U	390 U	380 U	380 U	380 U	390 U	390 U
bis(2-Ethylhexyl)Phthalate	380 U	390 U	45 J	47 J	380 U	46 J	390 U
Di-n-Octylphthalate	380 U	390 U	380 U	380 U	380 U	390 U	390 U
Benzo(b)fluoranthene	380 U	390 U	380 U	380 U	380 U	390 U	390 U
Benzo(k)fluoranthene	380 U	390 U	380 U	380 U	380 U	390 U	390 U
Benzo(a)Pyrene	380 U	390 U	380 U	380 U	380 U	390 U	390 U
Indeno(1,2,3-cd)pyrene	380 U	390 U	380 U	380 U	380 U	390 U	390 U
Dibenzo(a,h)anthracene	380 U	390 U	380 U	380 U	380 U	390 U	390 U
Benzo(g,h,i)Perylene	380 U	390 U	380 U	380 U	380 U	390 U	390 U

## NOTES:

UG/KG indicates micrograms per kilogram

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank



TABLE 5-15 (CONTINUED)

SEMI-VOLATILE ORGANIC COMPOUNDS DETECTED IN SOIL SAMPLES  
 SITE 13  
 PUBLIC WORKS PCP DIP TANK AND WASH RACK  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 AUGUST, 1995

SAMPLE NUMBER MATRIX UNITS	13SB-110-02 SOIL UG/KG	13SB-110-03 SOIL UG/KG	13SB-111-02 SOIL UG/KG	13SB-112-02 SOIL UG/KG	13SB-113-02 SOIL UG/KG	13SB-FB1 WATER UG/L	13SB-RB1 WATER UG/L	13SB-RB3 WATER UG/L
Phenol	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
bis(2-Chloroethyl) Ether	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
2-Chlorophenol	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
1,3-Dichlorobenzene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
1,4-Dichlorobenzene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
1,2-Dichlorobenzene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
2-Methylphenol	400 U	390 U	410 U	390 U	390 U	10 U	4 J	10 U
bis(2-Chloroisopropyl) Ether	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
4-Methylphenol	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
N-Nitrosodipropylamine	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
Hexachloroethane	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
Nitrobenzene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
Isophorone	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
2-Nitrophenol	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
2,4-Dimethylphenol	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
bis(2-Chloroethoxy) Methanol	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
2,4-Dichlorophenol	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
1,2,4-Trichlorobenzene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
Naphthalene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
4-Chloroaniline	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
Hexachlorobutadiene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
4-Chloro-3-methylphenol	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
2-Methylnaphthalene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
Hexachlorocyclopentadiene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
2,4,6-Trichlorophenol	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
2,4,5-Trichlorophenol	960 U	950 U	1000 U	950 U	940 U	26 U	25 U	26 U
2-Chloronaphthalene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
2-Nitroaniline	960 U	950 U	1000 U	950 U	940 U	26 U	25 U	26 U
Dimethylphthalate	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
Acenaphthylene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
2,6-Dinitrotoluene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
3-Nitroaniline	960 U	950 U	1000 U	950 U	940 U	26 U	25 U	26 U

## NOTES:

UG/KG indicates micrograms per kilogram

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

TABLE 5-15 (CONTINUED)

SEMI-VOLATILE ORGANIC COMPOUNDS DETECTED IN SOIL SAMPLES  
 SITE 13  
 PUBLIC WORKS PCP DIP TANK AND WASH RACK  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 AUGUST, 1995

SAMPLE NUMBER MATRIX UNITS	13SB-110-02 SOIL UG/KG	13SB-110-03 SOIL UG/KG	13SB-111-02 SOIL UG/KG	13SB-112-02 SOIL UG/KG	13SB-113-02 SOIL UG/KG	13SB-FB1 WATER UG/L	13SB-RB1 WATER UG/L	13SB-RB3 WATER UG/L
Acenaphthene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
2,4-Dinitrophenol	960 UJ	950 UJ	1000 UJ	950 U	940 U	26 U	25 U	26 U
4-Nitrophenol	960 U	950 U	1000 U	950 U	940 U	26 U	25 U	26 U
Dibenzofuran	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
2,4-Dinitrotoluene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
Diethylphthalate	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
4-Chlorophenylphenyl Ether	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
Fluorene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
4-Nitroaniline	960 U	950 U	1000 U	950 U	940 U	26 U	25 U	26 U
4,6-Dinitro-2-Methylphenol	960 U	950 U	1000 U	950 U	940 U	26 U	25 U	26 U
N-nitrosodiphenylamine	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
4-Bromophenylphenyl Ether	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
Hexachlorobenzene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
Pentachlorophenol	960 U	950 U	1000 U	950 U	940 U	26 U	25 U	26 U
Phenanthrene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
Anthracene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
Carbazole	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
Di-n-Butyl Phthalate	400 U	390 U	58 J	42 J	390 U	10 U	10 U	10 U
Fluoranthene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
Pyrene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
Butyl Benzyl Phthalate	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
3,3'-Dichlorobenzidine	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
Benzo(a)anthracene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
Chrysene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
bis(2-Ethylhexyl)Phthalate	400 U	390 U	46 J	390 U	100 J	10 U	10 U	10 U
Di-n-Octylphthalate	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
Benzo(b)fluoranthene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
Benzo(k)fluoranthene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
Benzo(a)Pyrene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
Indeno(1,2,3-cd)pyrene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
Dibenzo(a,h)anthracene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U
Benzo(g,h,i)Perylene	400 U	390 U	410 U	390 U	390 U	10 U	10 U	10 U

**NOTES:**

UG/KG indicates micrograms per kilogram

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

TABLE 5-16

**PESTICIDES AND PCBs DETECTED IN SOIL SAMPLES**  
**SITE 13**  
**PUBLIC WORKS PCP DIP TANK AND WASH RACK**  
**NAVAL AMPHIBIOUS BASE LITTLE CREEK**  
**VIRGINIA BEACH, VIRGINIA**  
**AUGUST, 1995**

SAMPLE NUMBER MATRIX UNITS	13SB-101-02 SOIL UG/KG	13SB-102-02 SOIL UG/KG	13SB10202MS SOIL UG/KG	13SB10202MSD SOIL UG/KG	13SB-103-02 SOIL UG/KG	13SB-FB1 WATER UG/L	13SB-RB1 WATER UG/L
alpha-BHC	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	0.050 U	0.050 U
beta-BHC	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	0.050 U	0.050 U
delta-BHC	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	0.050 U	0.050 U
gamma-BHC (Lindane)	2.0 U	2.0 U	16	15	2.0 U	0.050 U	0.050 U
Heptachlor	2.0 U	2.0 U	17	16	2.0 U	0.050 U	0.050 U
Aldrin	2.0 U	2.0 U	16	15	2.0 U	0.050 U	0.050 U
Heptachlor Epoxide	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	0.050 U	0.050 U
Endosulfan I	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	0.050 U	0.050 U
Dieldrin	3.9 U	3.9 U	34	34	3.8 U	0.10 U	0.10 U
4,4'-DDE	2.4 J	3.9 U	3.9 U	3.9 U	3.8 U	0.10 U	0.10 U
Endrin	3.9 U	3.9 U	31	32	3.8 U	0.10 U	0.10 U
Endosulfan II	3.9 U	3.9 U	3.9 U	3.9 U	3.8 U	0.10 U	0.10 U
4,4'-DDD	1.5 J	3.9 U	3.9 U	3.9 U	3.8 U	0.10 U	0.10 U
Endosulfan Sulfate	3.9 U	3.9 U	3.9 U	3.9 U	3.8 U	0.10 U	0.10 U
4,4'-DDT	3.9 U	3.9 U	34	34	3.8 U	0.10 U	0.10 U
Methoxychlor	20 U	20 U	20 U	20 U	20 U	0.5 U	0.50 U
Endrin Ketone	3.9 U	3.9 U	1.9 J	3.9 U	3.8 U	0.10 U	0.10 U
Endrin Aldehyde	3.9 U	3.9 U	1.7 JP	3.9 U	3.8 U	0.10 U	0.10 U
alpha-Chlordane	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	0.050 U	0.050 U
gamma-Chlordane	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U	0.050 U	0.050 U
Toxaphene	200 U	200 U	200 U	200 U	200 U	5.0 U	5.0 U
Aroclor 1016	39 U	39 U	39 U	39 U	38 U	1.0 U	1.0 U
Aroclor 1221	80 U	80 U	80 U	80 U	78 U	2.0 U	2.0 U
Aroclor 1232	39 U	39 U	39 U	39 U	38 U	1.0 U	1.0 U
Aroclor 1242	39 U	39 U	39 U	39 U	38 U	1.0 U	1.0 U
Aroclor-1248	39 U	39 U	39 U	39 U	38 U	1.0 U	1.0 U
Aroclor-1254	39 U	39 U	39 U	39 U	38 U	1.0 U	1.0 U
Aroclor-1260	39 U	39 U	39 U	39 U	38 U	1.0 U	1.0 U

**NOTES:**

UG/KG indicates micrograms per kilogram

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

TABLE 5-17

**INORGANIC COMPOUNDS DETECTED IN SOIL SAMPLES**  
**SITE 13**  
**PUBLIC WORKS PCP DIP TANK AND WASH RACK**  
**NAVAL AMPHIBIOUS BASE LITTLE CREEK**  
**VIRGINIA BEACH, VIRGINIA**  
**AUGUST, 1995**

SAMPLE NUMBER MATRIX UNITS	13SB-101-02 SOIL MG/KG	13SB-102-02 SOIL MG/KG	13SB-103-02 SOIL MG/KG	13SB-FB1 WATER UG/L	13SB-RB1 WATER UG/L
Aluminum	18,100	13,300	18,400	19.3 B	14.4 U
Antimony	3.5 J	3.50 UJ	3.4 UJ	14.8 U	14.8 U
Arsenic	4.00	2.60J	3.9	1.3 U	1.3 U
Barium	45 B	47.90	52.7	0.87 U	0.65 U
Beryllium	0.32 B	0.31 B	0.33 B	0.33 U	0.37 U
Cadmium	0.40 U	0.40 U	0.39 U	1.7 U	1.7 U
Calcium	430 B	492.00 J	424 B	11.1 U	49.6 JL
Chromium	21.2	13.80	18.9	1.6 U	1.6 U
Cobalt	3.5 B	2.50 B	3.0 B	2.0 U	2.0 U
Copper	5.4 B	3.40 B	4.0 B	4.7 U	4.7 U
Iron	14,600	9,150	15,200	13.9 U	6.7 U
Lead	9.2	7.50	9.4	1.6 U	1.6 U
Magnesium	934 B	755.00 B	988 B	18.0 B	15.4 U
Manganese	38.7	39.90	37.9	0.51 B	0.50 U
Mercury	0.12 U	0.12 U	0.12 U	0.20 U	0.20 U
Nickel	8.4 B	5.80 B	7.1 B	5.4 U	5.4 U
Potassium	518 B	430.00 U	484 B	498 U	361 U
Selenium	0.64 U	0.64 U	0.63 U	2.7 U	2.7 U
Silver	0.64 U	0.64 U	0.63 U	2.7 U	2.7 U
Sodium	84.0 B	103.00 B	143 B	137 U	66.0 U
Thallium	0.98U	0.97 U	0.95 U	4.1 U	4.1 U
Vanadium	28.6 J	19.40	27.8 J	0.90 U	0.90 U
Zinc	13.4	36.90	12.2	8.8 B	9.8 B
CN	3.0 U	3.00 U	2.9 U	5.0 U	5.0 U

**NOTES:**

MG/KG indicates milligrams per kilogram

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

Arsenic was detected in all three soil samples at levels ranging from 2.6 mg/kg (J) in 13SB-102-02 to 4 mg/kg in 13SB-101-02.

Barium was detected in samples 13SB-102-02 and 13SB-103-02 at 47.9 mg/kg and 52.7 mg/kg, respectively.

Calcium was detected in one sample, 13SB-102-02, at 492 mg/kg (J).

Chromium was detected in all three soil samples at levels ranging from 13.8 mg/kg in 13SB-102-02 to 21.2 mg/kg in 13SB-101-02.

Iron was detected in all three soil samples at levels ranging from 9,150 mg/kg in 13SB-102-02 to 15,200 mg/kg in 13SB-103-02.

Lead was detected in all three soil samples at levels ranging from 7.5 mg/kg in 13SB-102-02 to 9.4 mg/kg in 13SB-103-02.

Manganese was detected in all three soil samples at levels ranging from 37.9 mg/kg in 13SB-103-02 to 39.9 mg/kg in 13SB-102-02.

Vanadium was detected in all three soil samples at levels ranging from 19.4 mg/kg in 13SB-102-02 to 28.6 mg/kg (J) in 13SB-101-02.

Zinc was detected in all three soil samples at levels ranging from 12.2 mg/kg in 13SB-103-02 to 36.9 mg/kg in 13SB-102-02.

### Groundwater

Twelve groundwater samples were collected from monitoring wells at Site 13. All twelve samples were analyzed for VOCs and SVOCs, while three of the samples also were analyzed for pesticides and PCBs, and TAL metals.

### **VOCs**

VOCs were detected in ten of the twelve groundwater samples. **Table 5-18** presents a summary of TAL metals detected in soil, and associated quality control, samples at Site 13. Nine VOCs were detected in the groundwater samples, though each compound was not detected in each sample: chlorobenzene, 1,1-dichloroethene, 1,2-dichloroethene (total), ethylbenzene, tetrachloroethene, trichloroethene, toluene, vinyl chloride, and xylenes (total).

Chlorobenzene was detected in one sample, LC13-GW106, at 1 µg/l (J).

1,1-dichloroethene was detected in samples LC13-GW106 and LC13-GW110 at 3 µg/l (J) and 2 µg/l (J), respectively.

TABLE 6-18

VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER SAMPLES  
 SITE 13  
 PUBLIC WORKS PCP DIP TANK AND WASH RACK  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 AUGUST, 1995

SAMPLE NUMBER MATRIX UNITS	LC13-GW102 WATER UG/L	LC13-GW103 WATER UG/L	LC13-GW104 WATER UG/L	LC13-GW105 WATER UG/L	LC13-GW106 WATER UG/L	LC13-GW107 WATER UG/L	LC13-GW108 WATER UG/L	LC13-GW109 WATER UG/L	LC13-GW110 WATER UG/L	LC13-GW111 WATER UG/L
Methyl chloride	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Methyl bromide	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Vinyl Chloride	10 U	10 U	10 U	10 U	120	10 U	10 U	10 U	130 J	9 J
Chloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Methylene chloride	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Acetone	10 UJ	10 U	10 U	10 UJ	10 UJ	10 U	10 U	10 U	10 UJ	10 U
Carbon disulfide	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1-Dichloroethene	10 U	10 U	10 U	10 U	3 J	10 U	10 U	10 U	2 J	10 U
1,1-Dichloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,2-dichloroethene (Total	10 U	3 J	10 U	2 J	370 D	10 U	10 U	2 J	530 D	110 X
Chloroform	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,2-Dichloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Methyl ethyl ketone	10 UJ	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1,1-Trichloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Carbon tetrachloride	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Bromodichloromethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,2-Dichloropropane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
cis-1,3-Dichloropropene	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Trichloroethene	10 U	10 U	2 J	2 J	470 D	10 U	10 U	1 J	570 D	130
Dibromochloromethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1,2-Trichloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Benzene	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
trans-1,3-Dichloropropene	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Bromoform	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
4-Methyl-2-Pentanone	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
2-Hexanone	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Tetrachloroethene	10 U	10 U	2 J	10 U	1200 D	10 U	10 U	3 J	940 D	300 D
1,1,2,2-Tetrachloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Toluene	10 U	10 U	10 U	10 U	10 U	10 U	1 J	10 U	10 U	10 U
Chlorobenzene	10 U	10 U	10 U	10 U	1 J	10 U	10 U	10 U	10 U	10 U
Ethylbenzene	10 U	10 U	10 U	10 U	10 U	10 U	3 J	10 U	10 U	10 U
Styrene	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Xylene (total)	10 U	10 U	10 U	10 U	10 U	10 U	49	10 U	10 U	10 U

## NOTES:

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

D indicated samples diluted

B indicates compound detected in laboratory blank

TABLE 6-18 (CONTINUED)

## VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER SAMPLES

SITE 13

PUBLIC WORKS PCP DIP TANK AND WASH RACK

NAVAL AMPHIBIOUS BASE LITTLE CREEK

VIRGINIA BEACH, VIRGINIA

AUGUST, 1995

SAMPLE NUMBER MATRIX UNITS	LC13-GW112 WATER UG/L	LC13-GW113 WATER UG/L	LC13-GW114 WATER UG/L	LC13-GW115 WATER UG/L	LC13-GW-FB WATER UG/L	LC13-GW-RB WATER UG/L	TRIP BLANK 1 WATER UG/L	TRIPBLANK3 WATER UG/L
Methyl chloride	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Methyl bromide	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Vinyl Chloride	10 U	10 U	10 U	120 J	10 U	10 U	10 U	10 U
Chloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Methylene chloride	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Acetone	10 UJ	10 UJ	10 U	10 UJ	10 U	10 U	10 U	10 UJ
Carbon disulfide	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1-Dichloroethene	10 U	10 U	10 U	2 J	10 U	10 U	10 U	10 U
1,1-Dichloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,2-dichloroethene (Total	4 J	18	10 U	510 D	10 U	10 U	10 U	10 U
Chloroform	10 U	10 U	10 U	10 U	2 J	10 U	10 U	10 U
1,2-Dichloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Methyl ethyl ketone	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1,1-Trichloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Carbon tetrachloride	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Bromodichloromethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,2-Dichloropropane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
cis-1,3-Dichloropropene	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Trichloroethene	4 J	18	10 U	560 D	10 U	10 U	10 U	10 U
Dibromochloromethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
1,1,2-Trichloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Benzene	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
trans-1,3-Dichloropropene	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Bromoform	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
4-Methyl-2-Pentanone	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
2-Hexanone	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Tetrachloroethene	12	29	10 U	1000 D	10 U	10 U	10 U	10 U
1,1,2,2-Tetrachloroethane	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Toluene	10 U	10 U	1 J	10 U	10 U	10 U	10 U	10 U
Chlorobenzene	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Ethylbenzene	10 U	10 U	4 J	10 U	10 U	10 U	10 U	10 U
Styrene	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Xylene (total)	10 U	10 U	53 X	10 U	10 U	10 U	10 U	10 U

## NOTES:

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

D indicates samples diluted

B indicates compound detected in laboratory blank

1,2-dichloroethene (total) was detected eight of the twelve groundwater samples at levels ranging from 2 µg/l (J) in LC13-GW105 and LC13-GW109, to 530 µg/l (D) in LC13-GW110.

Ethylbenzene was detected in one sample, LC13-GW108, at 3 µg/l (J).

Tetrachloroethene was detected in seven of the twelve groundwater samples at levels ranging from 2 µg/l (J) in LC13-GW104 to 1,200 µg/l (D) in LC13-GW106.

Trichloroethene was detected in eight of the twelve groundwater samples at levels ranging from 1 µg/l (J) in LC13-GW109 to 570 µg/l (D) in LC13-GW110.

Toluene was detected in one sample, LC13-GW108, at 1 µg/l (J).

Vinyl chloride was detected in three of the twelve groundwater samples at levels ranging from 9 µg/l (J) in LC13-GW111 to 130 µg/l (J) in LC13-GW110.

Xylenes (total) were detected in one sample, LC13-GW108, at 49 µg/l.

#### SVOCs

SVOCs were detected in seven of the twelve groundwater samples. **Table 5-19** presents a summary of SVOCs detected in groundwater, and associated quality control, samples at Site 13. Eight SVOCs were detected in the groundwater samples, though each compound was not detected in each sample: bis(2-ethylhexyl)phthalate, fluorene, 2-methylnaphthalene, 4-methylphenol, naphthalene, pentachlorophenol, phenanthrene, and phenol.

Bis(2-ethylhexyl)phthalate was detected in LC13-GW108, LC13-GW109, and LC13-GW113 at 5 µg/l (J), 1 µg/l (J), and 1 µg/l (J), respectively. Bis(2-ethylhexyl)phthalate is a common laboratory contaminant.

Fluorene was detected in one sample, LC13-GW108, at 3 µg/l (J).

2-methylnaphthalene was detected in LC13-GW108 and LC13-GW112 at 120 µg/l and 2 µg/l (J), respectively.

4-methylphenol was detected in one sample, LC13-GW108, at 3 µg/l (J).

Naphthalene was detected in one sample, LC13-GW108, at 73 µg/l.

Pentachlorophenol was detected in seven of the twelve groundwater samples at levels ranging from 21 µg/l (J) in LC13-GW106 to 2,300 µg/l (D) in LC13-GW108.

Phenanthrene was detected in one sample, LC13-GW108, at 3 µg/l (J).

Phenol was detected in one sample, LC13-GW108, at 3 µg/l (J).



TABLE 6-19

SEMI-VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER SAMPLES  
 SITE 13  
 PUBLIC WORKS PCP DIP TANK AND WASH RACK  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 SEPTEMBER, 1995

SAMPLE NUMBER MATRIX UNITS	LC13-GW103 WATER UG/L	LC13-GW102 WATER UG/L	LC13-GW105 WATER UG/L	LC13-GW106 WATER UG/L	LC13-GW107 WATER UG/L	LC13-GW108 WATER UG/L	LC13-GW109 WATER UG/L	LC13-GW110 WATER UG/L
Phenol	11 U	11 U	11 U	11 U	11 U	3 J	10 U	11 U
bis(2-Chloroethyl) Ether	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
2-Chlorophenol	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
1,3-Dichlorobenzene	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
1,4-Dichlorobenzene	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
1,2-Dichlorobenzene	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
2-Methylphenol	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
bis(2-Chloroisopropyl)Ether	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
4-Methylphenol	11 U	11 U	11 U	11 U	11 U	3 J	10 U	11 U
N-Nitrosodipropylamine	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
Hexachloroethane	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
Nitrobenzene	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
Isophorone	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
2-Nitrophenol	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
2,4-Dimethylphenol	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
bis(2-Chloroethoxy)Methanol	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
2,4-Dichlorophenol	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
1,2,4-Trichlorobenzene	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
Naphthalene	11 U	11 U	11 U	11 U	11 U	73	10 U	11 U
4-Chloroaniline	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
Hexachlorobutadiene	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
4-Chloro-3-methylphenol	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
2-Methylnaphthalene	11 U	11 U	11 U	11 U	11 U	120	10 U	11 U
Hexachlorocyclopentadiene	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
2,4,6-Trichlorophenol	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
2,4,5-Trichlorophenol	28 U	26 U	27 U	26 U	26 U	54 U	25 U	28 U
2-Chloronaphthalene	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
2-Nitroaniline	28 U	26 U	27 U	26 U	26 U	54 U	25 U	28 U
Dimethylphthalate	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
Acenaphthylene	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
2,6-Dinitrotoluene	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
3-Nitroaniline	28 U	26 U	27 U	26 U	26 U	54 U	25 U	28 U

## NOTES:

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound found in laboratory blank

TABLE 5-19 (CONTINUED)

SEMI-VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER SAMPLES  
 SITE 13  
 PUBLIC WORKS PCP DIP TANK AND WASH RACK  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 SEPTEMBER, 1995

SAMPLE NUMBER MATRIX UNITS	LC13-GW103 WATER UG/L	LC13-GW102 WATER UG/L	LC13-GW105 WATER UG/L	LC13-GW106 WATER UG/L	LC13-GW107 WATER UG/L	LC13-GW108 WATER UG/L	LC13-GW109 WATER UG/L	LC13-GW110 WATER UG/L
Acenaphthene	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
2,4-Dinitrophenol	28 U	26 U	27 U	26 U	26 U	54 U	25 U	28 U
4-Nitrophenol	28 U	26 U	27 U	26 U	26 U	54 U	25 U	28 U
Dibenzofuran	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
2,4-Dinitrotoluene	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
Diethylphthalate	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
4-Chlorophenylphenyl Ether	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
Fluorene	11 U	11 U	11 U	11 U	11 U	3 J	10 U	11 U
4-Nitroaniline	28 U	26 U	27 U	26 U	26 U	54 U	25 U	28 U
4,6-Dinitro-2-Methylphenol	28 U	26 U	27 U	26 U	26 U	54 U	25 U	28 U
N-nitrosodiphenylamine	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
4-Bromophenylphenyl Ether	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
Hexachlorobenzene	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
Pentachlorophenol	83	26 U	27 U	21 J	26 U	2300 D	56	28 U
Phenanthrene	11 U	11 U	11 U	11 U	11 U	3 J	10 U	11 U
Anthracene	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
Carbazole	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
Di-n-Butyl Phthalate	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
Fluoranthene	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
Pyrene	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
Butyl Benzyl Phthalate	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
3,3'-Dichlorobenzidine	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
Benzo(a)anthracene	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
Chrysene	11 U	11 U	11 U	11 U	11 U	22 U	10 U	11 U
bis(2-Ethylhexyl)Phthalate	11 U	11 U	11 U	11 U	11 U	5 J	1 J	11 U
Di-n-Octylphthalate	11 U	11 U	110 R	11 U	11 U	22 U	10 U	11 U
Benzo(b)fluoranthene	11 U	11 U	110 R	11 U	11 U	22 U	10 U	11 U
Benzo(k)fluoranthene	11 U	11 U	110 R	11 U	11 U	22 U	10 U	11 U
Benzo(a)Pyrene	11 U	11 U	110 R	11 U	11 U	22 U	10 U	11 U
Indeno(1,2,3-cd)pyrene	11 U	11 U	110 R	11 U	11 U	22 U	10 U	11 U
Dibenzo(a,h)anthracene	11 U	11 U	110 R	11 U	11 U	22 U	10 U	11 U
Benzo(g,h,i)Perylene	11 U	11 U	110 R	11 U	11 U	22 U	10 U	11 U

## NOTES:

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

D indicates sample diluted

B indicates compound detected in laboratory blank

R indicates refected data

TABLE 5-19 (CONTINUED)

SEMI-VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER SAMPLES  
 SITE 13  
 PUBLIC WORKS PCP DIP TANK AND WASH RACK  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 SEPTEMBER, 1995

SAMPLE NUMBER MATRIX UNITS	LC13-GW111 WATER UG/L	LC13-GW111 MS WATER UG/L	LC13-GW111 MSD WATER UG/L	LC13-GW112 WATER UG/L	LC13-GW113 WATER UG/L	LC13-GW115 WATER UG/L	LC13-GW-FB WATER UG/L	LC13-GW-RB WATER UG/L
Phenol	10 U	39	33	11 U	11 U	10 U	11 U	10 U
bis(2-Chloroethyl) Ether	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
2-Chlorophenol	10 U	39	36	11 U	11 U	10 U	11 U	10 U
1,3-Dichlorobenzene	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
1,4-Dichlorobenzene	10 U	25	23	11 U	11 U	10 U	11 U	10 U
1,2-Dichlorobenzene	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
2-Methylphenol	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
bis(2-Chloroisopropyl) Ether	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
4-Methylphenol	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
N-Nitrosodipropylamine	10 U	23	21	11 U	11 U	10 U	11 U	10 U
Hexachloroethane	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
Nitrobenzene	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
Isophorone	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
2-Nitrophenol	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
2,4-Dimethylphenol	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
bis(2-Chloroethoxy)Methanol	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
2,4-Dichlorophenol	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
1,2,4-Trichlorobenzene	10 U	25	23	11 U	11 U	10 U	11 U	10 U
Naphthalene	10 U	11 U	11 U	4 B	2 B	10 U	11 U	2 J
4-Chloroaniline	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
Hexachlorobutadiene	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
4-Chloro-3-methylphenol	10 U	46	41	11 U	11 U	10 U	11 U	10 U
2-Methylnaphthalene	10 U	11 U	11 U	2 J	11 U	10 U	11 U	10 U
Hexachlorocyclopentadiene	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
2,4,6-Trichlorophenol	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
2,4,5-Trichlorophenol	25 U	28 U	28 U	26 U	27 U	25 U	28 U	26 U
2-Chloronaphthalene	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
2-Nitroaniline	25 U	28 U	28 U	26 U	27 U	25 U	28 U	26 U
Dimethylphthalate	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
Acenaphthylene	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
2,6-Dinitrotoluene	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
3-Nitroaniline	25 U	28 U	28 U	26 U	27 U	25 U	28 U	26 U

## NOTES:

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

TABLE 5-19 (CONTINUED)

SEMI-VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER SAMPLES  
 SITE 13  
 PUBLIC WORKS PCP DIP TANK AND WASH RACK  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 SEPTEMBER, 1995

SAMPLE NUMBER MATRIX UNITS	LC13-GW111 WATER UG/L	LC13-GW111 MS WATER UG/L	LC13-GW111 MSD WATER UG/L	LC13-GW112 WATER UG/L	LC13-GW113 WATER UG/L	LC13-GW115 WATER UG/L	LC13-GW-FB WATER UG/L	LC13-GW-RB WATER UG/L
Acenaphthene	10 U	29	24	11 U	11 U	10 U	11 U	10 U
2,4-Dinitrophenol	25 U	28 U	28 U	26 U	27 U	25 U	28 U	26 U
4-Nitrophenol	25 U	53	52	26 U	27 U	25 U	28 U	26 U
Dibenzofuran	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
2,4-Dinitrotoluene	10 U	35	34	11 U	11 U	10 U	11 U	10 U
Diethylphthalate	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
4-Chlorophenylphenyl Ether	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
Fluorene	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
4-Nitroaniline	25 U	28 U	28 U	26 U	27 U	25 U	28 U	26 U
4,6-Dinitro-2-Methylphenol	25 U	28 U	28 U	26 U	27 U	25 U	28 U	26 U
N-nitrosodiphenylamine	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
4-Bromophenylphenyl Ether	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
Hexachlorobenzene	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
Pentachlorophenol	63	130	110	480 D	320 D	25 U	28 U	26 U
Phenanthrene	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
Anthracene	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
Carbazole	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
Di-n-Butyl Phthalate	10 U	11 U	2 J	11 U	11 U	10 U	11 U	1 J
Fluoranthene	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
Pyrene	10 U	26	19	11 U	11 U	10 U	11 U	10 U
Butyl Benzyl Phthalate	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
3,3'-Dichlorobenzidine	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
Benzo(a)anthracene	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
Chrysene	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
bis(2-Ethylhexyl)Phthalate	10 U	11 U	2 J	11 U	1 J	10 U	11 U	10 U
Di-n-Octylphthalate	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
Benzo(b)fluoranthene	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
Benzo(k)fluoranthene	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
Benzo(a)Pyrene	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
Indeno(1,2,3-cd)pyrene	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
Dibenzo(a,h)anthracene	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U
Benzo(g,h,i)Perylene	10 U	11 U	11 U	11 U	11 U	10 U	11 U	10 U

**NOTES:**

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

D indicates sample diluted

B indicates detected in laboratory blank

## Pesticides and PCBs

**Table 5-20** presents a summary of pesticides and PCBs detected in groundwater, and associated quality control, samples at Site 13. Three pesticides, 4,4'-DDD, alpha-chlordane, and gamma-chlordane, were detected in sample LC13-GW111, at 0.053  $\mu\text{g/l}$  (J), 0.044  $\mu\text{g/l}$  (J), and 0.044  $\mu\text{g/l}$  (J), respectively. No pesticides and PCBs were detected in the other two groundwater samples.

## Total and Dissolved TAL Metals

Total and dissolved TAL metals were detected in all three of the groundwater samples analyzed for these compounds. **Table 5-21** presents a summary of TAL total and dissolved metals detected in groundwater, and associated quality control, samples at Site 13.

The following TAL metals were detected in the three groundwater samples collected at Site 13, though each compound was not necessarily detected in all three samples: total aluminum, total arsenic, total barium, total beryllium, total and dissolved calcium, total chromium, total copper, total and dissolved iron, total lead, total and dissolved magnesium, total and dissolved manganese, total nickel, total potassium, total selenium, total and dissolved sodium, total vanadium, and total and dissolved zinc.

Total aluminum was detected in all three groundwater samples at levels ranging from 74,500  $\mu\text{g/l}$  in LC13-GW110 to 134,000  $\mu\text{g/l}$  in LC13-GW111.

Total arsenic was detected in all three groundwater samples at levels ranging from 31.8  $\mu\text{g/l}$  in LC13-GW110 to 39.5  $\mu\text{g/l}$  in LC13-GW111.

Total barium was detected in all three groundwater samples at levels ranging from 218  $\mu\text{g/l}$  in LC13-GW110 to 358  $\mu\text{g/l}$  in LC13-GW111.

Total beryllium was detected in all three groundwater samples at levels ranging from 3.3  $\mu\text{g/l}$  (K) in LC13-GW109 to 4.8  $\mu\text{g/l}$  (K) in both LC13-GW110 and LC13-GW111.

Total calcium was detected in all three groundwater samples at levels ranging from 11,000  $\mu\text{g/l}$  in LC13-GW109 to 30,400  $\mu\text{g/l}$  in LC13-GW110. Dissolved calcium was detected in all three groundwater samples at levels ranging from 8,610  $\mu\text{g/l}$  in LC13-GW109 to 22,300  $\mu\text{g/l}$  in LC13-GW110.

Total chromium was detected in all three groundwater samples at levels ranging from 104  $\mu\text{g/l}$  in LC13-GW110 to 165  $\mu\text{g/l}$  in LC13-GW111.

Total copper was detected in all three groundwater samples at levels ranging from 28.7  $\mu\text{g/l}$  in LC13-GW109 to 48.5  $\mu\text{g/l}$  in LC13-GW111.

Total iron was detected in all three groundwater samples at levels ranging from 88,500  $\mu\text{g/l}$  in LC13-GW110 to 135,000  $\mu\text{g/l}$  in LC13-GW111. Dissolved iron was detected in all three groundwater samples at levels ranging from 11.2  $\mu\text{g/l}$  (J) in LC13-GW110 to 106  $\mu\text{g/l}$  (J) in LC13-GW109.

TABLE 5-20

PESTICIDES AND PCBs DETECTED IN GROUNDWATER SAMPLES  
 SITE 13  
 PUBLIC WORKS PCP DIP TANK AND WASH RACK  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 SEPTEMBER, 1995

SAMPLE NUMBER MATRIX UNITS	LC13-GW109 WATER UG/L	LC13-GW110 WATER UG/L	LC13-GW111 WATER UG/L	GW111MS WATER UG/L	GW111MSD WATER UG/L	LC13-GW115 WATER UG/L	LC13-GW-RB WATER UG/L
alpha-BHC	0.050 UJ	0.10 UJ	0.050 UJ	0.10 U	0.10 U	0.050 U	0.050 U
beta-BHC	0.050 UJ	0.10 UJ	0.050 UJ	0.10 U	0.10 U	0.050 U	0.050 U
delta-BHC	0.050 UJ	0.10 UJ	0.050 UJ	0.10 U	0.10 U	0.050 U	0.050 U
gamma-BHC (Lindane)	0.050 UJ	0.10 UJ	0.050 UJ	1.1	0.92	0.050 U	0.050 U
Heptachlor	0.050 UJ	0.10 UJ	0.050 UJ	1.0	0.82	0.050 U	0.050 U
Aldrin	0.050 UJ	0.10 UJ	0.050 UJ	0.99	0.80	0.050 U	0.050 U
Heptachlor Epoxide	0.050 UJ	0.10 UJ	0.050 UJ	0.10 U	0.10 U	0.050 U	0.050 U
Endosulfan I	0.050 UJ	0.10 UJ	0.050 UJ	0.10 U	0.10 U	0.050 U	0.050 U
Dieldrin	0.10 UJ	0.20 UJ	0.10 UJ	2.3	1.8	0.10 U	0.10 U
4,4'-DDE	0.10 UJ	0.20 UJ	0.10 UJ	0.20 U	0.20 U	0.10 U	0.10 U
Endrin	0.10 UJ	0.20 UJ	0.10 UJ	2.2 P	1.8	0.10 U	0.10 U
Endosulfan II	0.10 UJ	0.20 UJ	0.10 UJ	0.20 U	0.20 U	0.10 U	0.10 U
4,4'-DDD	0.10 UJ	0.20 UJ	0.053 J	0.17 J	0.10 J	0.10 U	0.10 U
Endosulfan Sulfate	0.10 UJ	0.20 UJ	0.10 UJ	0.20 U	0.20 U	0.10 U	0.10 U
4,4'-DDT	0.10 UJ	0.20 UJ	0.10 UJ	1.7	1.4	0.10 U	0.10 U
Methoxychlor	0.50 UJ	1.0 UJ	0.50 UJ	1.0 U	1.0 U	0.50 U	0.50 U
Endrin Ketone	0.10 UJ	0.20 UJ	0.10 UJ	0.073 J	0.052 J	0.10 U	0.10 U
Endrin Aldehyde	0.10 UJ	0.20 UJ	0.10 UJ	0.20 U	0.20 U	0.10 U	0.10 U
alpha-Chlordane	0.050 UJ	0.10 UJ	0.044 J	0.098 J	0.067 J	0.050 U	0.050 U
gamma-Chlordane	0.050 UJ	0.10 UJ	0.044 J	0.10	0.066 J	0.050 U	0.050 U
Toxaphene	5.0 UJ	10 UJ	5.0 UJ	10 U	10 U	5.0 U	5.0 U
Aroclor 1016	1.0 UJ	2.0 UJ	1.0 UJ	2.0 U	2.0 U	1.0 U	1.0 U
Aroclor 1221	2.0 UJ	4.0UJ	2.0 UJ	4.0 U	4.0 U	2.0 U	2.0 U
Aroclor 1232	1.0 UJ	2.0 UJ	1.0 UJ	2.0 U	2.0 U	1.0 U	1.0 U
Aroclor 1242	1.0 UJ	2.0 UJ	1.0 UJ	2.0 U	2.0 U	1.0 U	1.0 U
Aroclor-1248	1.0 UJ	2.0 UJ	1.0 UJ	2.0 U	2.0 U	1.0 U	1.0 U
Aroclor-1254	1.0 UJ	2.0 UJ	1.0 UJ	2.0 U	2.0 U	1.0 U	1.0 U
Aroclor-1260	1.0 UJ	2.0 UJ	1.0 UJ	2.0 U	2.0 U	1.0 U	1.0 U

## NOTES:

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

TABLE 5-21

**INORGANIC COMPOUNDS DETECTED IN GROUNDWATER SAMPLES**  
**SITE 13**  
**PUBLIC WORKS PCP DIP TANK AND WASH RACK**  
**NAVAL AMPHIBIOUS BASE LITTLE CREEK**  
**VIRGINIA BEACH, VIRGINIA**  
**SEPTEMBER, 1995**

SAMPLE NUMBER MATRIX UNITS	LC13-GW109 DIS WATER UG/L	LC13-GW109 WATER UG/L	LC13-GW110 DIS WATER UG/L	LC13-GW110 WATER UG/L	LC13-GW111 DIS WATER UG/L
Aluminum	31.80 B	102000.00	12.40 U	74500.00	20.40 B
Antimony	8.40 U	8.40 UL	8.40 U	8.40 UL	8.40 U
Arsenic	1.50 U	34.60	1.50 U	31.80	1.50 U
Barium	73.90 B	246.00	40.80 B	218.00	41.20 B
Beryllium	0.30 U	3.30 K	0.30 U	4.80 K	0.30 U
Cadmium	1.70 B	3.10 B	1.30 U	3.20 B	1.30 U
Calcium	8610.00	11000.00	22300.00	30400.00	12400.00
Chromium	1.80 U	115.00	1.80 U	104.00	1.80 U
Cobalt	3.10 U	31.00 B	3.10 U	24.90 B	3.10 U
Copper	2.70 U	28.70	2.70 U	28.80	2.70 U
Iron	106.00 J	105000.00	11.20 J	88500.00	80.30 J
Lead	1.50 U	36.20	1.50 U	36.40	1.50 U
Magnesium	5520.00	13000.00	5550.00	14800.00	3890.00 B
Manganese	844.00	1390.00	148.00	1070.00	109.00
Mercury	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U
Nickel	2.90 U	43.40	2.90 U	49.20	2.90 U
Potassium	1260.00 B	5730.00	2810.00 B	9380.00	1180.00 B
Selenium	2.50 U	9.80	2.50 U	7.70	2.50 U
Silver	1.80 U	1.80 U	1.80 U	1.80 U	1.80 U
Sodium	16100.00	16900.00	15100.00	16900.00	15600.00
Thallium	3.60 U	3.60 U	3.60 U	3.60 U	3.60 U
Vanadium	1.70 U	146.00	1.70 U	162.00	1.70 U
Zinc	50.00	109.00 J	22.30	171.00 J	30.90
CN	NA	5.00 U	NA	5.00 U	NA

**NOTES:**

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

K indicates results biased high

L indicates results biased low

NA indicates Not Analyzed

TABLE 5-21 (CONTINUED)

**INORGANIC COMPOUNDS DETECTED IN GROUNDWATER SAMPLES**  
**SITE 13**  
**PUBLIC WORKS PCP DIP TANK AND WASH RACK**  
**NAVAL AMPHIBIOUS BASE LITTLE CREEK**  
**VIRGINIA BEACH, VIRGINIA**  
**SEPTEMBER, 1995**

SAMPLE NUMBER MATRIX UNITS	LC13-GW111 WATER UG/L	LC13-GW115 DIS WATER UG/L	LC13-GW115 WATER UG/L	LC13-GW-RB WATER UG/L	LC13-GW-RB DIS WATER UG/L
Aluminum	134000.00	17.50 B	36300.00	144.00 B	12.90 B
Antimony	8.40 UL	8.40 U	8.40 UL	8.40 UN	8.40 U
Arsenic	39.50	1.50 U	16.70	1.50 U	1.50 U
Barium	358.00	72.40 B	119.00 B	2.50 B	3.00 B
Beryllium	4.80 K	0.30 U	3.30 K	0.30 U	0.30 U
Cadmium	3.80 B	1.30 U	2.90 B	1.30 U	1.30 U
Calcium	17900.00	24800.00	28400.00	209.00 B	101.00 B
Chromium	165.00	1.80 U	53.70	2.20 B	1.80 U
Cobalt	33.80 B	3.10 U	11.70 B	3.10 U	3.10 U
Copper	48.50	2.70 U	15.60 B	2.70 U	2.70 U
Iron	135000.00	13.90 J	43900.00	164.00	8.00 BJ
Lead	42.60	1.50 U	17.60	1.50 U	1.50 U
Magnesium	13300.00	6080.00	10300.00	39.50 B	17.30 B
Manganese	526.00	163.00	602.00	2.10 B	1.10 B
Mercury	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U
Nickel	66.70	2.90 U	25.20 B	2.90 U	2.90 U
Potassium	8010.00	2800.00 B	6370.00	100.00 B	99.20 B
Selenium	10.40	2.50 U	4.00 B	2.50 U	2.50 U
Silver	1.80 U	1.80 U	1.80 U	1.80 U	1.80 U
Sodium	17000.00	16700.00	16700.00	670.00 B	662.00 B
Thallium	3.60 U	3.60 U	3.60 U	3.60 U	3.60 U
Vanadium	208.00	1.70 U	82.90	1.70 U	1.70 U
Zinc	192.00 J	39.80	98.70 J	6.90 BJ	8.30 B
CN	5.00 U	NA	5.00 U	5.00 U	NA

**NOTES:**

UG/L indicates micrograms per liter

U indicates compound not detected above detection limit

J indicates an estimated value

B indicates compound detected in laboratory blank

K indicates result is biased high

L indicates results biased low

NA indicates Not Analyzed



Total lead was detected in all three groundwater samples at levels ranging from 36.2 µg/l in LC13-GW109 to 42.6 µg/l in LC13-GW111.

Total magnesium was detected in all three groundwater samples at levels ranging from 13,000 µg/l in LC13-GW109 to 14,800 µg/l in LC13-GW110. Dissolved magnesium was detected in LC13-GW109 and LC13-GW110 at 5,520 µg/l and 5,550 µg/l, respectively.

Total manganese was detected in all three groundwater samples at levels ranging from 526 µg/l in LC13-GW111 to 1,390 µg/l in LC13-GW109. Dissolved manganese was detected in all three groundwater samples at levels ranging from 109 µg/l in LC13-GW111 to 844 µg/l in LC13-GW109.

Total nickel was detected in all three groundwater samples at levels ranging from 43.4 µg/l in LC13-GW109 to 66.7 µg/l in LC13-GW111.

Total potassium was detected in all three groundwater samples at levels ranging from 5,730 µg/l in LC13-GW109 to 9,380 µg/l in LC13-GW110.

Total selenium was detected in all three groundwater samples at levels ranging from 7.7 µg/l in LC13-GW110 to 10.4 µg/l in LC13-GW111.

Total sodium was detected in all three groundwater samples at levels ranging from 16,900 µg/l in LC13-GW109 and LC13-GW110, to 17,000 µg/l in LC13-GW111. Dissolved sodium was detected in all three groundwater samples at levels ranging from 15,100 µg/l in LC13-GW110 to 16,100 µg/l in LC13-GW109.

Total vanadium was detected in all three groundwater samples at levels ranging from 146 µg/l in LC13-GW109 to 208 µg/l in LC13-GW111.

Total zinc was detected in all three groundwater samples at levels ranging from 109 µg/l (J) in LC13-GW109 to 192 µg/l (J) in LC13-GW111. Dissolved zinc was detected in all three groundwater samples at levels ranging from 22.3 µg/l in LC13-GW110 to 50 µg/l in LC13-GW109.

## **Anions**

A summary of **anions** detected in groundwater samples is presented in **Table 5-22**.

## **5.2 Quality Assurance Results**

Quality Assurance results are evaluated utilizing the analytical data obtained from QA/QC samples, which were collected in accordance with the Project Sampling and Analysis Plan and the Quality Assurance Project Plan (QAPP).

TABLE 5-22

ANIONS DETECTED IN GROUNDWATER SAMPLES  
 SITE 13  
 PUBLIC WORKS PCP DIP TANK AND WASH RACK  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 SEPTEMBER, 1995

SAMPLE NUMBER MATRIX UNITS	LC13-GW102 09/20/95 MG/L	LC13-GW103 09/20/95 MG/L	LC13-GW104 09/20/95 MG/L	LC13-GW105 09/20/95 MG/L	LC13-GW106 09/20/95 MG/L	LC13-GW107 09/20/95 MG/L	LC13-GW108 09/20/95 MG/L
FLUORIDE	1.000 U	1.000 U	1.000 U	1.000 U	1.000 U	1.000 U	1.000 U
CHLORIDE	8.500	15.000	8.800	18.000	15.000	14.000	14.000
NITRATE	.500 U	.500 U	1.400	.900	.500 U	.500 U	.500 U
PHOSPHATE	1.000 U	1.000 U	1.000 U	1.000 U	1.000 U	1.000 U	1.000 U
SULFATE (SO42-)	14.000	26.000	34.000	22.000	34.000	34.000	22.000

**NOTES:**

MG/L indicates milligrams per liter

U indicates compound not detected above detection limit

TABLE 5-22 (CONTINUED)

ANIONS DETECTED IN GROUNDWATER SAMPLES  
 SITE 13  
 PUBLIC WORKS PCP DIP TANK AND WASH RACK  
 NAVAL AMPHIBIOUS BASE LITTLE CREEK  
 VIRGINIA BEACH, VIRGINIA  
 SEPTEMBER, 1995

SAMPLE NUMBER MATRIX UNITS	LC13-GW114 * 09/20/95 MG/L	LC13-GW109 09/20/95 MG/L	LC13-GW110 09/20/95 MG/L	LC13-GW111 09/20/95 MG/L	LC13-GW112 09/20/95 MG/L	LC13-GW113 09/20/95 MG/L
FLUORIDE	1.000 U	1.000 U	1.000 U	1.000 U	1.000 U	1.000 U
CHLORIDE	14.000	16.000	19.000	16.000	21.000	14.000
NITRATE	.500 U	1.400	.500 U	.500 U	1.900	1.600
PHOSPHATE	1.000 U	1.000 U	1.000 U	1.000 U	1.000 U	1.000 U
SULFATE (SO <sub>4</sub> <sup>2-</sup> )	22.000	32.000	47.000	34.000	33.000	36.000

**NOTES:**

MG/L indicates milligrams per liter

U indicates compound not detected above detection limit

\* indicates duplicate of sample LC13-GW108

These samples included:

- Field duplicate samples collected to assess the overall precision of the sampling and analysis program;
- Trip blanks for evaluating potential volatile organic compounds cross-contamination during sample shipment and storage;
- Field blanks to evaluate potential cross-contamination by the deionized water being used for rinsing; and,
- Equipment rinsate blanks to assess potential cross-contamination during sampling equipment decontamination procedures.

Trip blanks were analyzed only for target compounds list (TCL) volatile organic compounds (VOCs). Field duplicates, field blanks, and equipment rinsate blanks were analyzed for the same parameters as the environmental samples with which they were associated (ie. VOCs, SVOCs, Pesticides/PCBs, TAL metals, etc.).

The laboratory analytical results (data packages) were validated for completeness, quality assurance/quality control compliance, and to determine usability of the results in meeting the data quality objectives (DQOs) established in order to achieve the project objectives.

For the analytical parameters analyzed following USEPA Contract Laboratory Program (CLP); the organic data packages were validated following the guidelines identified in "Laboratory Data Validation Functional Guidelines for Evaluating Organic Analysis, June, 1991," and specific method requirements specified in OLMO1.8. The CLP inorganic data were validated utilizing the "Laboratory Data Validation Guidelines for Evaluating Inorganic Analysis, July 1, 1988," and specific method requirements specified in ILMO2.1, and NEESA Level D requirements.

The data for non-CLP analytical parameters have been validated utilizing specific analytical method requirements and NEESA Level C or E requirements. In all cases the USEPA CLP data qualifiers were utilized and assigned to the analytical results, when applicable, during the data review process.

## Site 12

Acetone was reported at low concentrations in the blanks associated with the subsurface soil, groundwater, sediment, and surface water environmental samples. This may be attributed to cross contamination from other sources. Chloroform was also detected in the blanks associated with the groundwater samples. Common metals were reported at trace level concentrations in one rinsate blank associated with groundwater samples from this site. Benzene also was detected in a rinsate sample associated with the subsurface soil samples. These minute detected concentrations have no impact on the usability of the groundwater data. The trace levels of acetone reported in the samples may be attributable to decontamination procedures rather than the virgin environmental samples.

## Site 13

Acetone was detected in one blank, while chloroform was detected in two blanks, associated with the subsurface soil samples. Chloroform also was detected in one blank associated with the groundwater samples for the site. One SVOC was reported in a blank associated with the subsurface soil data. Two SVOCs, naphthalene and di-n-butyl phthalate, were detected in blanks associated with the groundwater samples. These trace level contaminants reported in the blanks have no impact on the usability of the site data.

### **5.3 Identification of Chemicals of Concern**

#### **5.3.1 Criteria and Standards**

Identification of Chemicals of Concern (COCs) in soil and water media has been addressed by different procedures. The subsurface soil and sediment sample results have been compared to the soil concentrations listed in the United States Environmental Protection Agency (EPA) Region III Risk-Based Concentration (RBC) Table for residential soils, December 1995. These RBCs were used as Data Screening Concentrations (DSCs) for this SRI. The EPA Region III RBC Table is contained in Appendix H. The groundwater and surface water sample results have been compared to both the Federal Maximum Contaminant Levels (MCLs), promulgated under the Safe Drinking Water Act (SDWA) in May 1993 and the Virginia State Water Control Board (VSWCB) Water Quality Standards (WQSs), May 1992, as well as the RBCs for tap water. The MCLs include both the primary and secondary standards. The Federal MCLs and VSWCB WQSs have been applied to surface water sample results for comparison purposes only, since the Little Creek site is tidally influenced and brackish. The Federal and Virginia State Water Quality Standards are contained in Appendix I.

#### **5.3.2 Data Comparison with Previous Studies**

This study was conducted as a supplemental remedial investigation (SRI) to the RI/FS completed by FWES at the base in 1993. The following presents a comparison of the chemical data generated during the RI/FS and that generated during the SRI.

##### **5.3.2.1 Site 12 - Exchange Laundry Waste Disposal Area**

#### **Groundwater**

In addition to the four monitoring wells installed and sampled during the RI/FS, five new monitoring wells were installed and sampled during the SRI.

A comparison between VOCs detected during the RI/FS sampling and those detected during the SRI sampling indicated the following:

- Four VOCs were detected in the samples from both studies, with 1,2-dichloroethene (total), trichloroethene, and tetrachloroethene being common to both studies.

Chloroform, a common laboratory contaminant, was detected in one groundwater sample of the RI/FS, while vinyl chloride was detected in one groundwater sample of the SRI.

- The RI/FS indicated the highest levels of VOCs were detected in monitoring well LC12-GW2. Trace levels of VOCs were detected in monitoring wells LC12-GW3 and LC12-GW4. No VOCs were detected in monitoring well LC12-GW1.

The SRI indicated the highest levels of VOCs were detected in monitoring well LC12-GW4, while no VOCs were detected in monitoring well LC12-GW2. This may indicate a west/southwesterly movement of the VOC groundwater plume. Monitoring well LC12-GW5, located to the northeast of monitoring well LC12-GW2, contained the next highest levels of VOCs. Trace to low levels of VOCs were detected in all of the other monitoring wells.

### **Surface Water**

Four surface water samples were collected during both the RI/FS and the SRI. The samples collected as part of the RI/FS were collected in the drainage canal, immediately to the west of Site 12. The samples collected as part of the SRI were collected in the same drainage canal, though approximately 500 to 1,000 feet to the north, towards Lake Bradford.

The samples collected during the RI/FS contained six VOCs, including acetone, 1,2-dichloroethene (total), 2-butanone, trichloroethene, tetrachloroethene, and toluene. Only one VOC, acetone, was detected in the surface water samples collected during the SRI. Acetone is a common laboratory contaminant.

TAL metals were detected in the samples collected during both studies. The metals of most concern, such as arsenic, cadmium, copper, lead, and zinc, were detected at significantly lower levels in the samples collected during the SRI compared to those of the RI/FS.

The distance between the sampling areas of the two studies is likely the predominant reason for the discrepancies in the levels of compounds detected.

### **Sediment**

Four sediment samples were collected during both the RI/FS and the SRI. The samples collected as part of the RI/FS were collected in the drainage canal, immediately to the west of Site 12. The samples collected as part of the SRI were collected in the same drainage canal, though approximately 500 to 1,000 feet to the north, towards Lake Bradford. All sediment samples were collected at locations corresponding with the surface water samples.

The samples collected during the RI/FS contained six VOCs, including acetone, 1,2-dichloroethene (total), trichloroethene, tetrachloroethene, toluene, and xylenes (total). Only two VOCs, acetone and chlorobenzene, were detected in the surface water samples collected during the SRI. Acetone is a common laboratory contaminant, and chlorobenzene was detected at a trace level.

TAL metals were detected in the samples collected during both studies. The metals of most concern, such as arsenic, cadmium, copper, lead, and zinc, were detected at significantly lower levels in the samples collected during the SRI compared to those of the RI/FS.

The distance between the sampling areas of the two studies is likely the predominant reason for the discrepancies in the levels of compounds detected.

#### 5.3.2.2 Site 13 - Public Work PCP Dip Tank and Wash Rack

##### **Subsurface Soil**

Surface soil samples were collected as part of the RI/FS and contained significant levels of VOCs, primarily those collected in the area of the former PCP dip tank. Subsurface soils collected during the RI/FS contained only trace levels of VOCs.

Only trace levels of five VOCs were detected in the subsurface soils collected during the SRI. Of particular note is the presence of only trace levels of VOCs in four of the eight subsurface soil samples collected from the area of the former PCP dip tank. This indicates the contamination present in the source area only lies within the top 6 inches of soil.

Pentachlorophenol was the predominant SVOC detected in the subsurface soil samples collected during the RI/FS. Similarly, pentachlorophenol was the only SVOC detected at a relatively high level in the subsurface soil samples collected during the SRI, though the levels detected were significantly less than those observed during the RI/FS.

##### **Groundwater**

In addition to the eight monitoring wells installed and sampled during the RI/FS, five new monitoring wells were installed and sampled during the SRI.

A comparison between VOCs detected during the RI/FS sampling and those detected during the SRI sampling indicated the following:

- The highest levels of VOCs detected in both studies were at monitoring well LC13-GW6, though the levels detected in the sample collected during the SRI were significantly higher than those observed during the RI/FS.
- Trace levels of a number of other VOCs, including 1,2-dichloroethene, vinyl chloride, trichloroethene, and tetrachloroethene, were detected in the majority of samples of both studies.
- Moderate levels of 1,2-dichloroethene, vinyl chloride, trichloroethene, and tetrachloroethene, were detected in two of the new monitoring wells installed during the SRI. Trace levels were observed in the other three new monitoring wells.

As with the subsurface soil samples, pentachlorophenol was the SVOC detected at the highest levels in both studies. The highest level of pentachlorophenol detected during the RI/FS was in monitoring well LC13-GW8. Similarly, monitoring well LC13-GW8 also contained the highest level of pentachlorophenol during the SRI. The level of pentachlorophenol detected during the SRI was slightly higher than that detected during the RI/FS.

#### **5.4     Extent of Constituents of Concern**

The chemicals which are detected at the site above the applicable criteria discussed in Section 5.3.1, are considered the constituents of concern. Their distribution at various sampling locations and among media of concern are mapped. Aluminum, iron, sodium, potassium, calcium, and magnesium can be found naturally in all media and are not further evaluated. Due to the random distribution of the constituent occurrences, the data is presented as a map of constituent distribution. Such figures can be used to draw preliminary conclusions about the potential sources of those constituents.

The following sections present a summary of the horizontal extent of the impact to soil and groundwater at NAB Little Creek sites. It is presented in the order which represents the migration pathways from a potential source: subsurface soil, groundwater, surface water, and sediments.

##### **5.4.1   Site 12 - Exchange Laundry Waste Disposal Area**

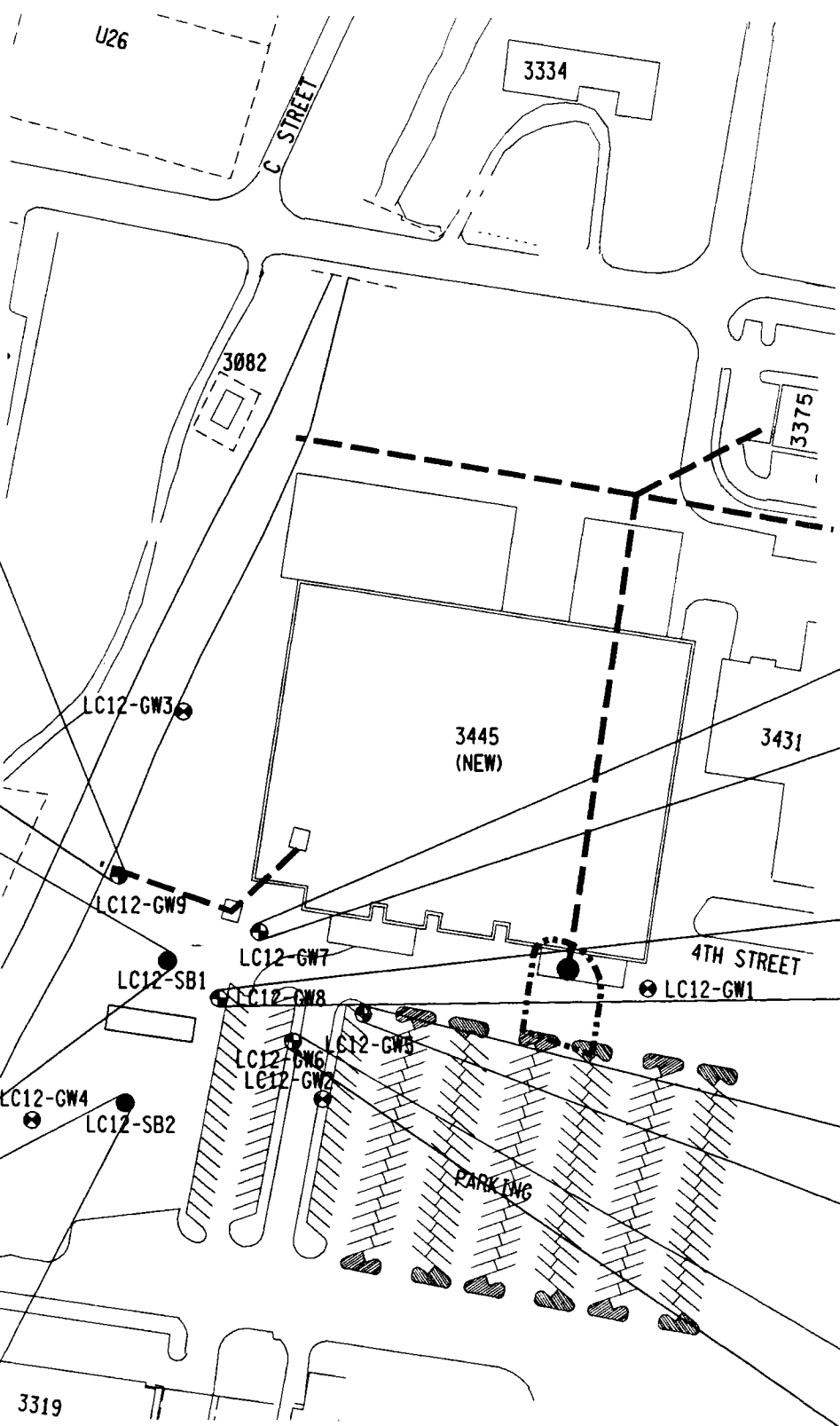
###### **Subsurface Soil**

No VOCs, SVOCs, or Pesticides/PCBs were detected at levels which exceeded their respective standards. Only one TAL metal was detected at a level which exceeded its respective standards. Lead exceeded both the residential and industrial USEPA RBC of 0.78  $\mu\text{g/kg}$  and 20  $\mu\text{g/kg}$ , respectively in all but one soil sample. The level of lead detected in 12SB-101-06 was below both the residential and industrial USEPA RBCs. The highest levels of lead were detected in the area of monitoring wells LC12-GW7 and LC12-GW9, and soil boring LC12-SB01, though the distribution of lead detected in the subsurface soil at Site 12 does not present a distinctive trend. **Figure 5-1** presents the distribution of the detected metals. Values are not shown from monitoring wells LC12-GW1, LC12-GW2, LC12-GW3, and LC12-GW4 because they were sampled and installed during the RI/FS.

###### **Groundwater**

Volatile Organics have been detected above their respective standards in groundwater. The distribution of volatile organic compounds is shown on **Figure 5-2**. Values are not shown for monitoring well LC12-GW2 because no VOCs were detected. Exceedances of both the USEPA RBC for tap water and the USEPA Drinking Water MCL were observed in a number of groundwater samples. Vinyl chloride was detected in LC12-GW4 at 980  $\mu\text{g/l}$ , which exceeded its MCL of 2  $\mu\text{g/l}$  and USEPA RBC of 1.9  $\mu\text{g/l}$ . Trichloroethene was detected in LC12-GW4, LC12-GW5, LC12-GW6, and LC12-GW7 at 760  $\mu\text{g/l}$ , 26  $\mu\text{g/l}$  (J), 12  $\mu\text{g/l}$ , and 18  $\mu\text{g/l}$  (J), respectively, which exceeded its MCL of 5  $\mu\text{g/l}$ , and its USEPA RBC of 1.6  $\mu\text{g/l}$ . Trichloroethene also was detected in LC12-GW1 and LC12-GW8 at 2  $\mu\text{g/l}$  (J), which exceeded its USEPA RBC of 1.6  $\mu\text{g/l}$ . Tetrachloroethene was detected in LC12-GW4, LC12-GW5,





12SB-111-02	
COMPOUND	CONCENTRATION (mg/kg)
Arsenic	4.60
Chromium	21.00
Copper	7.20
Lead	9.60
Manganese	45.70
Vanadium	28.00J
Zinc	19.00

12SB-101-05	
COMPOUND	CONCENTRATION (mg/kg)
Arsenic	4.00
Chromium	24.00
Copper	6.10
Lead	9.90
Manganese	40.20
Vanadium	29.40J
Zinc	18.60

12SB-102-02	
COMPOUND	CONCENTRATION (mg/kg)
Arsenic	2.00J
Chromium	12.10
Lead	7.50
Manganese	27.60
Vanadium	18.40J
Zinc	13.00

12SB-109-02	
COMPOUND	CONCENTRATION (mg/kg)
Arsenic	2.60
Chromium	13.40
Copper	6.70
Lead	11.70
Manganese	57.00
Vanadium	13.50J
Zinc	16.90

12SB-110-02	
COMPOUND	CONCENTRATION (mg/kg)
Arsenic	3.00
Chromium	11.20
Lead	8.00
Manganese	34.60
Vanadium	18.90J
Zinc	12.80

12SB-107-03	
COMPOUND	CONCENTRATION (mg/kg)
Arsenic	2.90
Chromium	17.20
Lead	8.30
Manganese	19.30
Vanadium	21.80
Zinc	13.00

12SB-108-02	
COMPOUND	CONCENTRATION (mg/kg)
Arsenic	2.20J
Chromium	11.90
Lead	6.70
Manganese	15.90
Vanadium	21.80J
Zinc	11.50

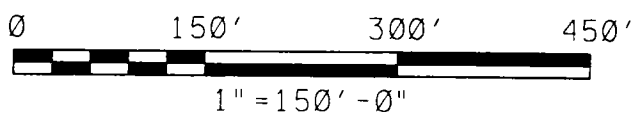
NOTES:


1. mg/kg indicates milligrams per kilogram.
2. J indicates an estimated value.
3. Aluminum, Calcium, Iron, Magnesium, Potassium, and Sodium values are reflected in data tables.

LEGEND

- FORMER WATER AND STORM SEWER LINE
- - - - - SITE BOUNDARY
- SOIL BORING
- LC12-SB1 MONITORING WELL INSTALLED BY FWES
- LC12-GW5 EXISTING MONITORING WELL INSTALLED BY FWES

GRAPHIC SCALE



REV.	DATE	DESCRIPTION	APPR.
REVISIONS			
FIGURE 5-1			
INORGANIC COMPOUNDS DETECTED IN SOIL SAMPLES SITE 12 NAB - LITTLE CREEK VIRGINIA BEACH, VIRGINIA			
<div> This Drawing is the property of the <b>FOSTER WHEELER ENVIRONMENTAL SERVICES</b> LIVINGSTON, NEW JERSEY <small>AND IS LENT WITHOUT CONSIDERATION OTHER THAN THE BORROWER'S AGREEMENT THAT IT SHALL NOT BE RE- PRODUCED, COPIED, LENT, OR DISPOSED OF DIRECTLY OR INDIRECTLY NOR USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT IS SPECIFICALLY FURNISHED.</small></div>			
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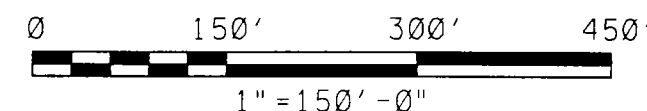
## NOTES:

1. ug/L indicates micrograms per Liter.
2. J indicates an estimated value.
3. D indicates sample diluted.

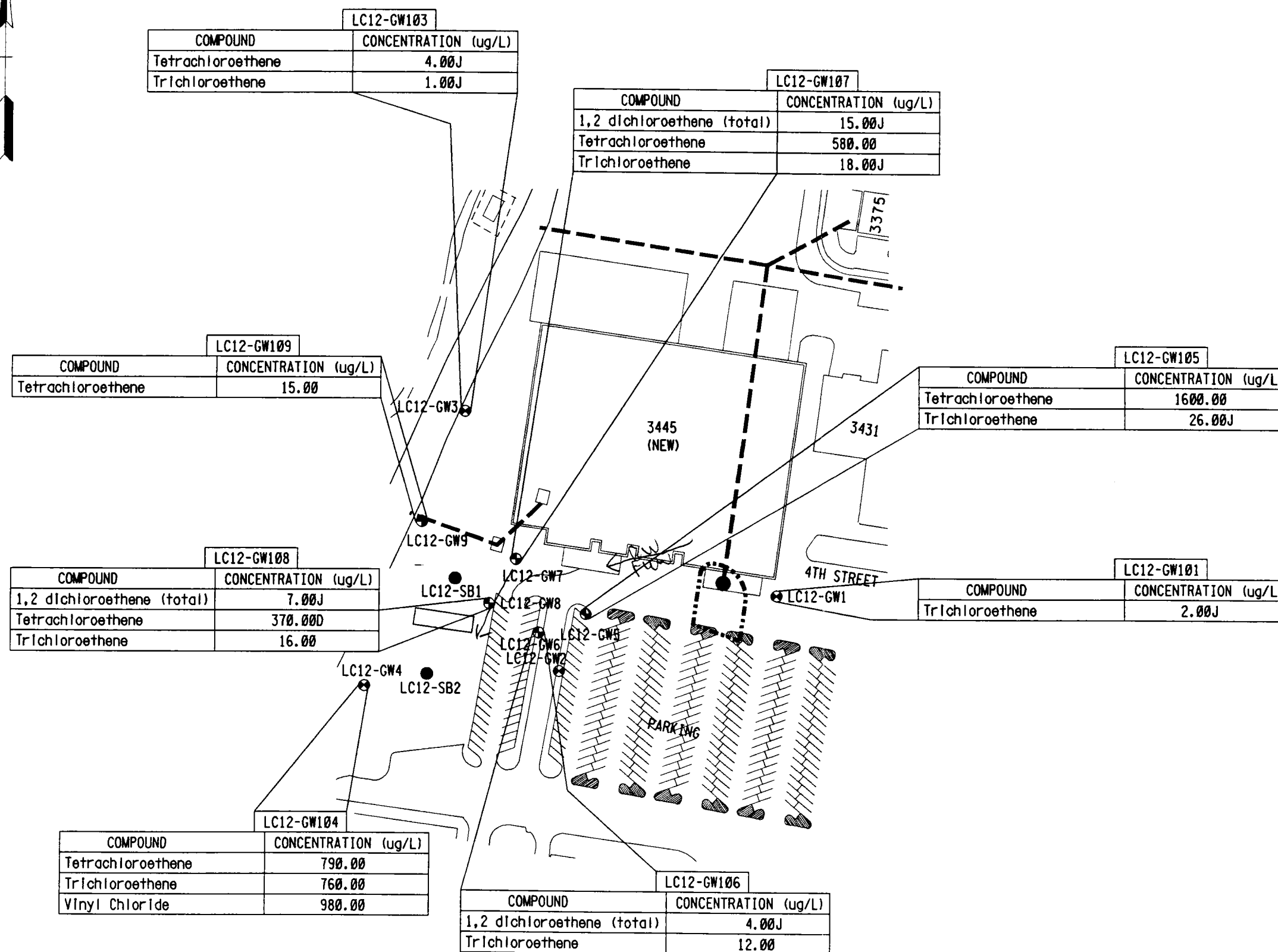
## LEGEND

- FORMER WATER AND STORM SEWER LINE
- SITE BOUNDARY
- SOIL BORING
- LC12-SB1 MONITORING WELL INSTALLED BY FWES
- LC12-GW5 EXISTING MONITORING WELL INSTALLED BY FWES
- LC12-GW1

## GRAPHIC SCALE



REV.	DATE	DESCRIPTION	APPR.
REVISIONS			
FIGURE 5-2			
VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER SAMPLES SITE 12 NAB - LITTLE CREEK VIRGINIA BEACH, VIRGINIA			
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		REV.	



LC12-GW7, LC12-GW8, and LC12-GW9 at 790 ug/l, 1,600 ug/l, 580 ug/l, 38 ug/l, and 15 ug/l, respectively, which exceeded its MCL of 5 ug/l, and its USEPA RBC of 1.1 ug/l. Tetrachloroethene also was detected in LC12-GW3 at 4 ug/l (J), which exceeded its USEPA RBC of 1.1 ug/l. LC12-GW4, LC12-GW5, and LC12-GW7 contained the highest levels of VOCs at Site 12, though the distribution of VOCs detected in the groundwater at Site 12 does not present a distinctive trend.

Only one SVOC was detected in one location, LC12-GW3, at a level which was an exceedance. bis(2-Chloroisopropyl)ether was detected at 10 ug/l (J), which exceeded its USEPA RBC of 0.26 ug/l.

Pesticides were detected in LC12-GW5 at levels which were exceedances. Heptachlor epoxide was detected at 0.038 ug/l (J), which exceeded its USEPA RBC of 0.0012 ug/l. alpha-chlordane was detected at 0.081 ug/l (J), and gamma-Chlordane was detected at 0.046 ug/l (J), which when combined, exceeded its USEPA RBC of 0.052 ug/l. LC12-GW2 contained aldrin at 0.015 ug/l (J), which exceeded its USEPA RBC of 0.004 ug/l. LC12-GW4 contained total chlordane at 0.119, which exceeded its USEPA RBC of 0.052 ug/l. Since these pesticides are not known to have been used during on-site activities, their presence in groundwater samples is most likely due to vegetative control measures conducted at the site.

A number of TAL metals were detected above their respective standards in the groundwater. The majority of TAL metals which were exceedances were observed in the total metal phase, though a number of dissolved metals were also detected at levels above their respective standards. **Figure 5-3** presents the distribution of the detected total metals, while **Figure 5-4** presents the distribution of the detected dissolved metals.

Total aluminum was detected at levels which exceeded its MCL of 50-200 ug/l in all groundwater samples, ranging from 15,200 ug/l at LC12-GW6 to 96,700 at LC12-GW2. Total aluminum exceeded its USEPA RBC of 37,000 ug/l at six of the nine locations, with levels ranging from 52,500 ug/l at LC12-GW1 to 96,700 ug/l at LC12-GW2.

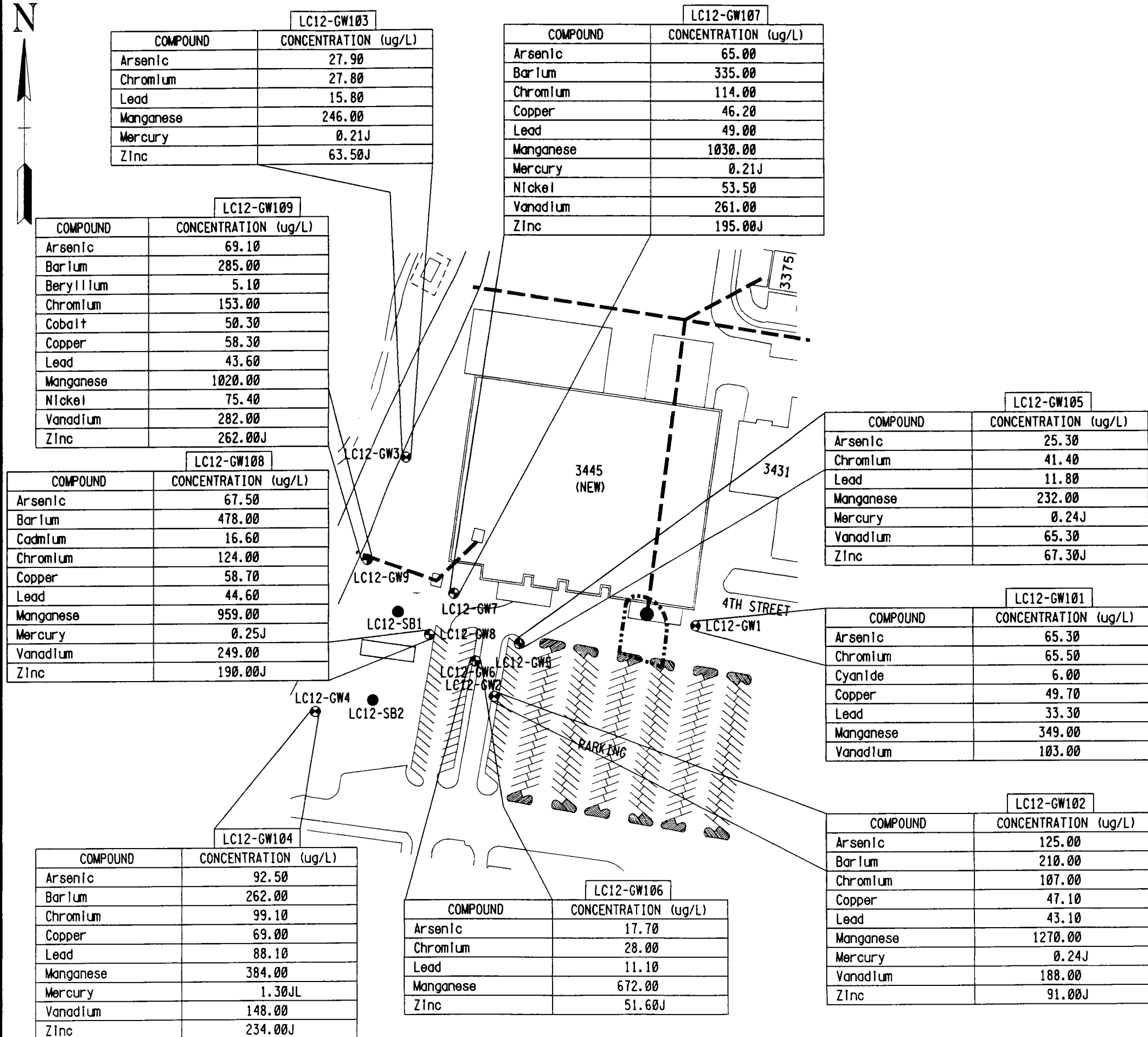
Total arsenic was detected at levels which exceeded both its MCL and Virginia Water Quality Standard (WQS) of 50 ug/l at six of the nine locations ranging from 65 ug/l at LC12-GW7 to 125 ug/l at LC12-GW2. Total arsenic was detected at levels which exceeded its USEPA RBC of 11 ug/l at all groundwater locations, ranging from 17.7 ug/l at LC12-GW6 to 125 ug/l at LC12-GW2.

Total beryllium was detected at levels which exceeded both its MCL of 4 ug/l and its USEPA RBC of 0.016 ug/l at one location. Total beryllium was detected at LC12-GW9 at 5.1 ug/l.

Total cadmium was detected at levels which exceeded both its MCL of 5 ug/l and its Virginia WQS of 0.4 ug/l, as well as its USEPA RBC of 18 ug/l, at one location. Total cadmium was detected at LC12-GW8 at 16.6 ug/l.

Total chromium was detected at levels which exceeded its Virginia WQS of 50 ug/l at six of the nine locations, ranging from 65.5 ug/l at LC12-GW1 to 153 ug/l at LC12-GW9. A number of these samples also exceeded the MCL of 100 ug/l, ranging from 107 ug/l at LC12-GW2 to 153 ug/l at LC12-GW9.

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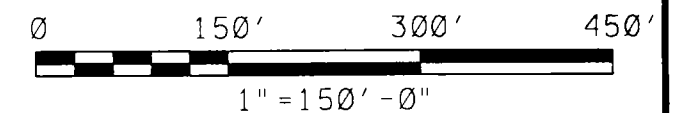
## NOTES:

1. ug/L Indicates micrograms per Liter.
2. J indicates an estimated value.
3. Aluminum, Calcium, Iron, Magnesium, Potassium, and Sodium values are reflected in data tables.

## LEGEND

- FORMER WATER AND STORM SEWER LINE
- ..... SITE BOUNDARY
- SOIL BORING
- LC12-SB1 MONITORING WELL INSTALLED BY FWES
- LC12-GW5
- ⊗ EXISTING MONITORING WELL INSTALLED BY FWES
- LC12-GW1

## GRAPHIC SCALE



REV.	DATE	DESCRIPTION	APPR.
REVISIONS			
FIGURE 5-3			
TOTAL INORGANIC COMPOUNDS DETECTED IN GROUNDWATER SAMPLES SITE 12 NAB - LITTLE CREEK VIRGINIA BEACH, VIRGINIA			
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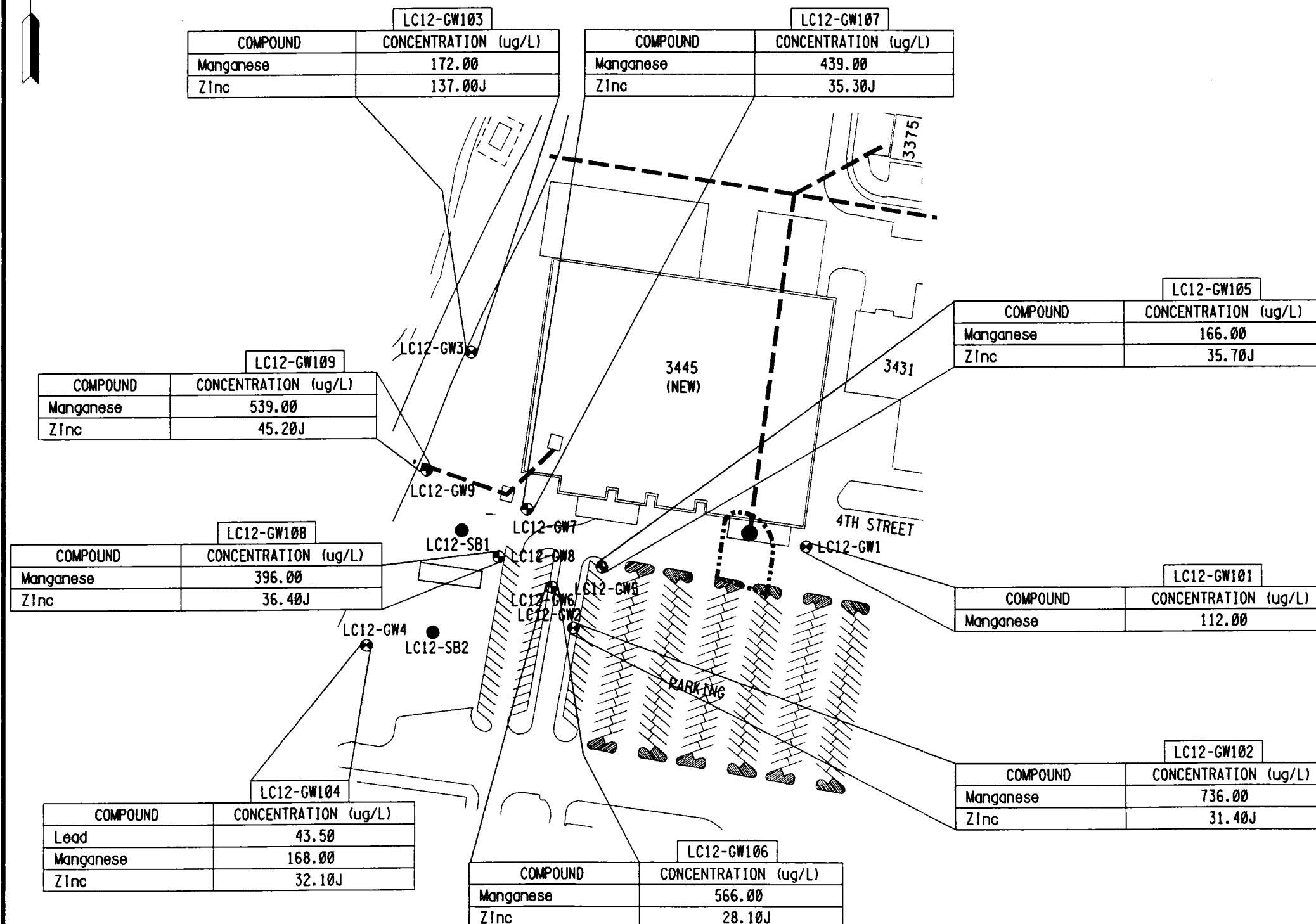
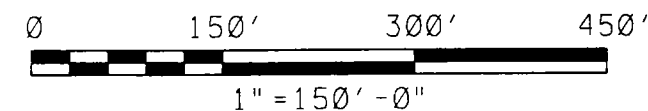
## NOTES:


1. ug/L Indicates micrograms per Liter.
2. J indicates an estimated value.
3. Aluminum, Calcium, Iron, Magnesium, Potassium, and Sodium values are reflected in data tables.

## LEGEND

- FORMER WATER AND STORM SEWER LINE
- ..... SITE BOUNDARY
- SOIL BORING
- LC12-SB1 MONITORING WELL INSTALLED BY FWES
- ⊗ EXISTING MONITORING WELL INSTALLED BY FWES
- LC12-GW1

## GRAPHIC SCALE



REV.	DATE	DESCRIPTION	APPR.
REVISIONS			
FIGURE 5-4			
DISSOLVED INORGANIC COMPOUNDS DETECTED IN GROUNDWATER SAMPLES SITE 12 NAB - LITTLE CREEK VIRGINIA BEACH, VIRGINIA			
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Total lead was detected at levels which exceeded its USEPA RBC of 0.0037 ug/l at all locations, ranging from 11.1 ug/l at LC12-GW6 to 88.1 ug/l at LC12-GW4. Total lead detected at LC12-GW4 also was detected at levels which exceeded its Virginia WSQ of 50 ug/l. Dissolved lead also was detected at LC12-GW4 at 43.5 ug/l, which exceeded its USEPA RBC of 0.0037 ug/l.

Total manganese was detected at levels which exceeded both its USEPA RBC of 180 ug/l and its MCL of 50 ug/l at all locations, ranging from 232 ug/l at LC12-GW5 to 1,270 ug/l at LC12-GW2. Dissolved manganese was detected at levels which exceeded both its USEPA RBC of 180 ug/l and its MCL of 50 ug/l at five of the nine locations, ranging from 390 ug/l in the duplicate sample from LC12-GW8 to 736 ug/l at LC12-GW2.

Total mercury was detected at levels which exceeded its Virginia WQS of 0.05 ug/l at six of the nine locations at levels ranging from 0.21 ug/l (J) at LC12-GW3 and LC12-GW7, to 1.3 ug/l (JL) at LC12-GW4.

Total cyanide was detected at levels which exceeded its Virginia WQS of 5 ug/l at one location. Total cyanide was detected at 6 ug/l at LC12-GW1.

#### Surface Water

Only two total TAL metals were detected at levels which exceeded their respective standards. Aluminum was detected at 293 µg/l in LC12-SW-107 and 344 µg/l in the duplicate of LC12-SW-105, which both exceed the MCL of 50-200 ug/l. Manganese was detected at 188 µg/l in LC12-SW-105 and 208 ug/l in LC12-SW-108, which both exceed the USEPA RBC of 180 ug/l. All four samples contained manganese at levels which exceeded its MCL of 50 ug/l, ranging from 103 ug/l in LC12-SW-106 to 208 ug/l in LC12-SW-108.

#### Sediments

Only one TAL metal was detected above its respective standard in the sediment. Lead was detected above both its residential and industrial USEPA RBCs of 0.0078 mg/kg and 0.2 mg/kg, respectively, ranging from 3.8 mg/kg at LC12-SED-108 to 101 mg/kg at LC12-SED-107.

### **5.4.2 Site 13 - Public Works PCP Dip Tank and Wash Rack**

#### Subsurface Soils

No VOCs, SVOCs, or Pesticides/PCBs were detected in subsurface soils at levels which exceeded their respective standards. Only one TAL metal, lead, was detected at levels which exceeded both its residential and industrial USEPA RBCs of 0.0078 mg/kg and 0.2 mg/kg, respectively. Lead was detected at levels ranging from 7.5 mg/kg in 13SB-102-02 to 9.4 in 13SB-103-02.

## Groundwater

The distribution of VOCs detected in groundwater is shown on **Figure 5-5**. No values are shown for monitoring well LC13-GW1 because it was not sampled during the SRI. No values are shown for monitoring wells LC13-GW2 and LC13-GW7 because no VOCs were detected. Vinyl chloride was detected at levels which exceeded both the MCL of 2 ug/l and the USEPA RBC of 0.019 ug/l. Vinyl chloride was detected at levels ranging from 9 ug/l (J) at LC13-GW11 to 130 ug/l (J) at LC13-GW10. 1,1-dichloroethene was detected at levels which exceeded the USEPA RBC of 0.044 ug/l. 1,1-dichloroethene was detected at 2 ug/l (J) in LC13-GW10 and 3 ug/l (J) in LC13-GW6. 1,2-dichloroethene (total) was detected at levels which exceeded both the MCL of 70 ug/l and the USEPA RBC of 55 ug/l. 1,2-dichloroethene (total) was detected at levels ranging from 110 ug/l in LC13-GW11 to 530 ug/l (D) in LC13-GW10. Trichloroethene was detected at levels which exceeded both the MCL of 5 ug/l and the USEPA RBC of 1.6 ug/l. Trichloroethene was detected at levels ranged from 18 ug/l in LC13-GW13 to 570 ug/l (D) in LC13-GW10. Trichloroethene also was detected at levels which exceeded just the USEPA RBC of 1.6 ug/l, at 2 ug/l (J) in LC13-GW4 and LC13-GW5, and 4 ug/l (J) in LC13-GW12. Tetrachloroethene was detected at levels which exceeded both the MCL of 5 ug/l and the USEPA RBC of 1.1 ug/l. Tetrachloroethene was detected at levels ranged from 12 ug/l in LC13-GW12 to 1,200 ug/l (D) in LC13-GW6. Tetrachloroethene also was detected at levels which exceeded just the USEPA RBC of 1.1 ug/l, at 2 ug/l (J) in LC13-GW4 and 3 ug/l (J) in LC13-GW9.

The distribution of SVOCs detected in groundwater is shown on **Figure 5-6**. No values are shown for monitoring well LC13-GW1 because it was not sampled during the SRI. No values are shown for monitoring wells LC13-GW2, LC13-GW4, LC13-GW5, LC13-GW7, and LC13-GW10 because no SVOCs were detected. Phenol was detected in one location at a level which exceeded the Virginia WQS of 1 ug/l. LC13-GW8 contained phenol at 3 ug/l (J). Pentachlorophenol was detected at levels which exceeded both the MCL of 1 ug/l as well as the USEPA RBC of 0.56 ug/l. Pentachlorophenol was detected as levels ranging from 21 ug/l (J) in LC13-GW6 to 2,300 ug/l (D) in LC13-GW8. bis(2-ethylhexyl)phthalate, a common laboratory contaminant, was detected in LC13-GW8 at 5 ug/l (J), which exceeds the USEPA RBC of 4.8 ug/l.

No pesticides/PCBs were detected at levels which exceeded their respective standards. Since pesticides are not known to have been used during on-site activities, the low levels detected in groundwater samples is most likely due to vegetative control measures conducted at the site.

A number of TAL metals were detected above their respective standards in the groundwater. The majority of TAL metals which were exceedances were observed in the total metal phase, though a dissolved manganese was also detected in one sample at levels above its respective standards. **Figure 5-7** presents the distribution of the detected total metals, while **Figure 5-8** presents the distribution of the detected dissolved metals. No values are shown for monitoring well LC13-GW1 because it was not sampled during the SRI. No values are shown for monitoring wells LC13-GW2 through LC13-GW8, LC13-GW12, and LC13-GW13 because the groundwater samples collected from these wells were not analyzed for TAL metals.

1. ug/L indicates micrograms per Liter.
2. J indicates an estimated value.
3. D indicates sample diluted.

### LEGEND



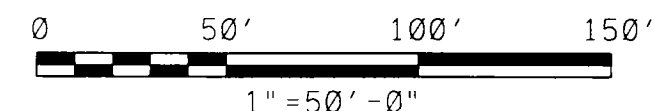
LOCATION OF FORMER  
PCP DIP TANK

SITE BOUNDARY

LC13-GW10

MONITORING WELL LOCATION

GRAPHIC SCALE



REV.	DATE	DESCRIPTION	APPR
REVISIONS			

FIGURE 5-5  
VOLATILE ORGANIC COMPOUNDS  
DETECTED IN  
GROUNDWATER SAMPLES  
SITE 13  
NAB - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA



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## NOTES:

1. ug/L indicates micrograms per Liter.
2. J indicates an estimated value.
3. D indicates sample diluted.

## LEGEND

LOCATION OF FORMER  
PCP DIP TANK

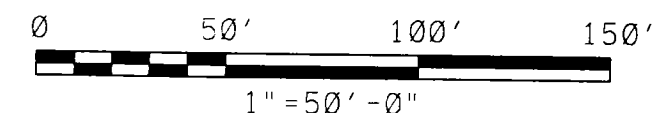
SITE BOUNDARY

LC13-GW10



MONITORING WELL LOCATION

## GRAPHIC SCALE



REV.	DATE	DESCRIPTION	APPR.
REVISIONS			
FIGURE 5-6			
SEMI-VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER SAMPLES			
SITE 13			
NAB - LITTLE CREEK VIRGINIA BEACH, VIRGINIA			
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LC13-GW108	
COMPOUND	CONCENTRATION (ug/L)
Fluorene	3.00J
bis(2-Ethylhexyl)Phthalate	5.00J
4-Methylphenol	3.00J
2-Methylnaphthalene	120.00
Naphthalene	73.00
Pentachlorophenol	2300.00D
Phenanthrene	3.00J
Phenol	3.00J

LC13-GW103	
COMPOUND	CONCENTRATION (ug/L)
Pentachlorophenol	83.00

LC13-GW106	
COMPOUND	CONCENTRATION (ug/L)
Pentachlorophenol	21.00J

LC13-GW113	
COMPOUND	CONCENTRATION (ug/L)
Pentachlorophenol	320.00D
bis(2-Ethylhexyl)Phthalate	1.00J

LC13-GW111	
COMPOUND	CONCENTRATION (ug/L)
Pentachlorophenol	63.00

LC13-GW112	
COMPOUND	CONCENTRATION (ug/L)
2-Methylnaphthalene	2.00J
Pentachlorophenol	480.00D

LC13-GW109	
COMPOUND	CONCENTRATION (ug/L)
Pentachlorophenol	56.00
bis(2-Ethylhexyl)Phthalate	1.00J

LC13-GW12

LC13-GW10  
LC13-GW9

LC13-GW4

LC13-GW7

LC13-GW5

LC13-GW8

LC13-GW5

LC13-GW6

LC13-GW13

LC13-GW1

LC13-GW2

O/W SEP.

CONCRETE  
WASH  
PAD AREA

3165E

3165B

3165D

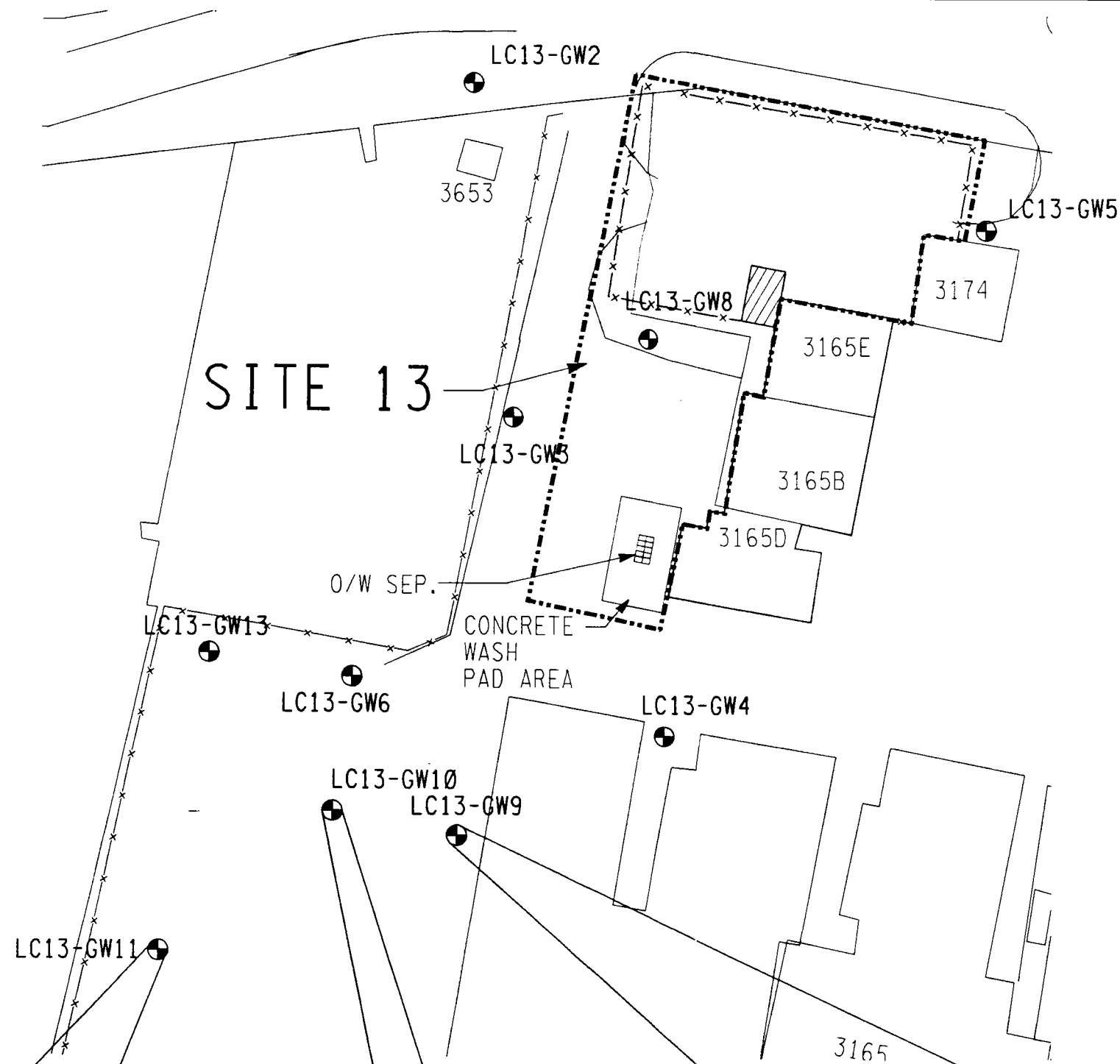
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## NOTES:

1. ug/L Indicates micrograms per Liter.
2. J indicates an estimated value.
3. K indicates results is biased high.
4. Aluminum, Calcium, Iron, Magnesium, Potassium, and Sodium values are reflected in data tables.

## LEGEND



LOCATION OF FORMER  
PCP DIP TANK



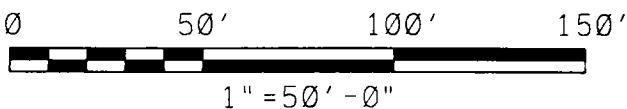
SITE BOUNDARY

LC13-GW10



MONITORING WELL LOCATION

## GRAPHIC SCALE



LC12-GW11	
COMPOUND	CONCENTRATION (mg/kg)
Arsenic	39.50
Barium	358.00
Beryllium	4.80K
Chromium	165.00
Copper	48.50
Lead	42.60
Manganese	526.00
Nickel	66.70
Selenium	10.40
Vanadium	208.00
Zinc	192.00J

LC12-GW10	
COMPOUND	CONCENTRATION (mg/kg)
Arsenic	31.80
Barium	218.00
Beryllium	4.80K
Chromium	104.00
Copper	28.80
Lead	36.40
Manganese	1070.00
Nickel	49.20
Selenium	7.70
Vanadium	162.00
Zinc	171.00J

LC12-GW9	
COMPOUND	CONCENTRATION (mg/kg)
Arsenic	34.60
Barium	246.00
Beryllium	3.30K
Chromium	115.00
Copper	28.70
Lead	36.20
Manganese	1390.00
Nickel	43.40
Selenium	9.80
Vanadium	146.00
Zinc	109.00J

REV.	DATE	DESCRIPTION	APPR.
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### REVISIONS

FIGURE 5-7

TOTAL INORGANIC COMPOUNDS  
DETECTED IN GROUNDWATER SAMPLES

SITE 13  
NAB - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA



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LIVINGSTON, NEW JERSEY

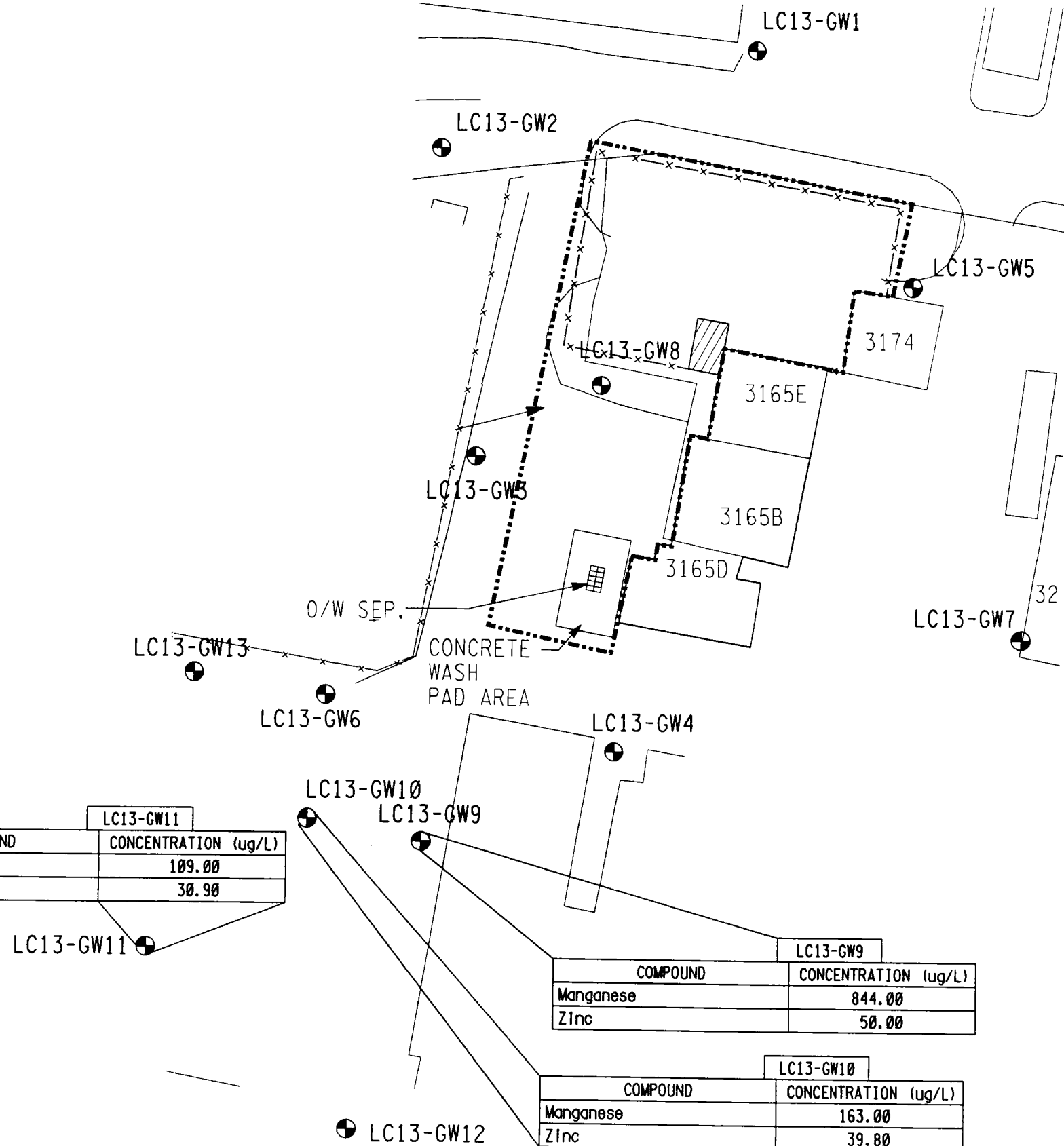
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LC13-GW11	
COMPOUND	CONCENTRATION (ug/L)
Manganese	109.00
Zinc	30.90

LC13-GW9	
COMPOUND	CONCENTRATION (ug/L)
Manganese	844.00
Zinc	50.00

LC13-GW10	
COMPOUND	CONCENTRATION (ug/L)
Manganese	163.00
Zinc	39.80

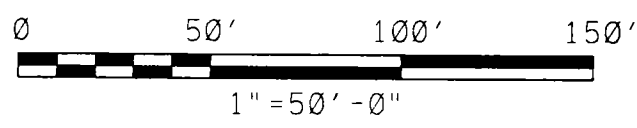
NOTES:

1. ug/L Indicates micrograms per Liter.
2. Aluminum, Calcium, Iron, Magnesium, Potassium, and Sodium values are reflected in data tables.

LEGEND

- LOCATION OF FORMER PCP DIP TANK
- SITE BOUNDARY
- LC13-GW10 MONITORING WELL LOCATION

GRAPHIC SCALE



REV.	DATE	DESCRIPTION	APPR.
REVISIONS			
FIGURE 5-8			
DISSOLVED INORGANIC COMPOUNDS DETECTED IN GROUNDWATER SAMPLES			
SITE 13			
NAB - LITTLE CREEK VIRGINIA BEACH, VIRGINIA			
This Drawing is the property of the <b>FOSTER WHEELER ENVIRONMENTAL SERVICES</b> LIVINGSTON, NEW JERSEY AND IS LENT WITHOUT CONSIDERATION OTHER THAN THE BORROWER'S AGREEMENT THAT IT SHALL NOT BE RE- PRODUCED, COPIED, LENT, OR DISPOSED OF DIRECTLY OR INDIRECTLY NOR USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT IS SPECIFICALLY FURNISHED.			
DRAWN BY: SAW		12/12/95	SCALE: 1"=50'-0"
CHECKED BY:			DRAWING No.
APPROVED BY:			0247-4-48-1316

CAD Rev No  
00 12-DEC-95

Total aluminum was detected at levels which exceeded both its MCL of 50-200 ug/l and its USEPA RBC of 37,000 ug/l in all groundwater samples, ranging from 74,500 ug/l at LC13-GW10 to 134,000 at LC13-GW11.

Total arsenic was detected at levels which exceeded its USEPA RBC of 11 ug/l at all groundwater locations, ranging from 31.8 ug/l at LC13-GW10 to 39.5 at LC13-GW11.

Total beryllium was detected at levels which exceeded both its MCL of 4 ug/l and its USEPA RBC of 0.016 ug/l at two locations. Total beryllium was detected at both LC13-GW10 and LC13-GW11 at 4.8 ug/l (K). Total beryllium also was detected at 3.3 ug/l (K) at LC13-GW9, which exceeded only its USEPA RBC of 0.016 ug/l.

Total chromium was detected at levels which exceeded both its MCL of 100 ug/l and its Virginia WQS of 50 ug/l. Total chromium was detected at levels ranging from 104 ug/l at LC13-GW10 to 165 ug/l at LC13-GW11.

Total lead was detected at levels which exceeded its USEPA RBC of 0.0037 ug/l at all locations, ranging from 36.2 ug/l at LC13-GW9 to 42.6 ug/l at LC13-GW11.

Total manganese was detected at levels which exceeded both its USEPA RBC of 180 ug/l and its MCL of 50 ug/l at all locations, ranging from 526 ug/l at LC13-GW11 to 1,390 ug/l at LC13-GW9. Dissolved manganese was detected at levels which exceeded both its USEPA RBC of 180 ug/l and its MCL of 50 ug/l at all locations, ranging from 109 ug/l at LC13-GW11 to 844 ug/l at LC13-GW9.

## **6.0 BASELINE RISK ASSESSMENT**

This section provides an addendum to the Baseline Risk Assessment (RA) for sites 12 and 13 at NAB Little Creek located in Virginia Beach, Virginia. Available data evaluation estimating the potential human health risks associated with current and future exposure under a no action scenario is provided. This addendum to the Baseline Risk Assessment follows the same format and is consistent with the Baseline Risk Assessment assumptions and exposure parameters. All toxicological values used in this addendum were updated as of December 1995.

### **6.1 Risk Assessment Data Base**

This risk assessment for sites 12 and 13 used the data bases from both the RI/FS and Supplemental RI. The site 12 data base included ten groundwater samples from the Columbia aquifer, nine surface water samples from the adjacent drainage canal, nine sediment samples from the same location as the surface water samples, collected from the 0-6 inch depth; and subsurface soil collected from 0-2 feet to the top of the water table. No fish samples were collected however use of bioconcentration factors from surface water were used to estimate the potential risk from fish consumption.

The site 13 data base included the six surface soil samples collected from 0-6 inches in depth as well as nineteen subsurface soils collected below 6 inches to the top of the water table. Twenty-one groundwater samples were also used in the site 13 risk assessment.

### **6.2 Chemicals of Concern**

This section discusses the chemicals of concern (COCs) selected for inclusion in the amended baseline RA for the two sites. COCs are site-related chemicals used to quantitatively estimate potential human and environmental exposures and associated health and ecological effects. The COCs were selected from the analytical data obtained during the RI. In determining a chemical selection as a COC, frequency of detection, contaminant concentration (compared to criteria and standards), and toxicity of the contaminant were also evaluated. The prevalence of chemical detection in other environmental media at a site was considered. This conservative approach is reflected in **Tables 6-1 and 6-2**, which summarize the chemicals of concern selection criteria for the individual sites evaluated.

Chemicals detected in 5% or more of the samples in a given site media were initially retained as chemicals of concern if 20 or more samples were obtained. When 10 to 19 samples were obtained in a given media, chemicals detected in 10% or more of the samples were initially retained. If 1 to 9 samples were obtained in a given media, chemicals detected in 20% or more of the samples were initially retained as chemicals of concern. Additional COCs were retained, even if below the specified frequency of detection levels, criteria and/or standards, dependent on their prevalence in other site media, analytical results obtained in earlier investigations, and historical site usage.

TABLE 6-1

**CHEMICALS OF CONCERN SELECTION CRITERIA  
SITE 12  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

	Media	Selection Criteria Not Met						Retained for Evaluation		
		Detection Frequency	Fact. Unavail. Bkg. Const.	Common Laboratory Contaminant	Federal & State Standards	Health Advisory	Risk Based Screening Levels	Detection Frequency	Criteria Met	Detected Otherwise/ Hist. Pres.
Dichloro-ethene, 1,2-	Surface water							X	X	X
	Ground water							X	X	
	Sediment							X		X
	Biota (fish)				X	X	X	X		X
Chloroform	Ground water							X		
Trichloro-ethene	Surface water							X	X	X
	Groundwater							X	X	
	Sediment							X		X
	Biota (fish)							X	X	
Tetrachloro-ethene	Surface water							X	X	
	Ground water							X	X	
	Sediment							X	X	
	Biota (fish)							X	X	
	Soil							X	X	
Acetone	Surface water			X			X			
	Sediment			X			X			
	Biota (fish)			X			X			
Butanone, 2-	Surface water			X						
	Sediment			X						
	Biota (fish)			X						
Toluene	Surface water				X	X	X			
	Sediment				X	X	X			
	Biota (fish)				X	X	X			
	Soil							X	X	
Xylene (total)	Sediment					X	X			
Aluminum	Surface water							X	X	
	Sediment							X		X
	Biota (fish)		X					X	X	
	Soil							X	X	
Arsenic	Surface water							X	X	
	Sediment							X	X	
	Biota (fish)							X	X	
	Soil							X	X	

TABLE 6-1 (CONTINUED)

**CHEMICALS OF CONCERN SELECTION CRITERIA  
SITE 12  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

Constituent	Media	Selection Criteria Not Met						Retained for Evaluation		
		Detection Frequency	Fact. Unavail. Bkg. Const.	Common Laboratory Contaminant	Federal & State Standards	Health Advisory	Risk Based Screening Levels	Detection Frequency	Criteria Met	Detected Otherwise/ Hist. Pres.
Barium	Surface water							X	X	
	Sediment							X		X
	Biota (fish)		X							
	Soil							X	X	
Beryllium	Surface water							X	X	
	Biota (fish)							X	X	
	Soil							X	X	
Cadmium	Surface water							X	X	
	Sediment							X		X
	Biota (fish)							X		X
Calcium	Surface water		X							
	Sediment		X							
	Biota (fish)		X							
Chromium	Surface water							X	X	
	Sediment							X		X
	Biota (fish)							X	X	
	Soil							X	X	
Cobalt	Surface water							X	X	
	Sediment							X		X
	Biota (fish)		X							
	Soil							X	X	
Copper	Surface water							X		X
	Sediment							X	X	
	Biota (fish)							X		X
	Soil							X	X	
Iron	Surface water							X	X	
	Sediment							X	X	
	Biota (fish)		X							
	Soil							X	X	
Lead	Surface water							X	X	
	Sediment							X	X	
	Biota (fish)							X	X	
	Soil							X	X	
Magnesium	Surface water		X							
	Sediment		X							
	Biota (fish)		X							

TABLE 6-1 (CONTINUED)

**CHEMICALS OF CONCERN SELECTION CRITERIA  
SITE 12  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

Constituent	Media	Selection Criteria Not Met						Retained for Evaluation		
		Detection Frequency	Fact. Unavail. Bkg. Const.	Common Laboratory Contaminant	Federal & State Standards	Health Advisory	Risk Based Screening Levels	Detection Frequency	Criteria Met	Detected Otherwise/ Hist. Pres.
Manganese	Surface water							X	X	X
	Sediment							X	X	
	Biota (fish)		X					X	X	
	Soil									
Mercury	Surface water							X	X	
	Sediment							X		X
	Biota (fish)							X		X
Nickel	Surface water							X	X	
	Sediment							X	X	X
	Biota (fish)							X	X	
	Soil									
Potassium	Surface water		X							
	Sediment		X							
	Biota (fish)		X							
Sodium	Surface water		X							
	Sediment		X							
	Biota (fish)		X							
Vanadium	Surface water							X	X	
	Sediment							X		X
	Biota (fish)		X					X	X	
	Soil									
Zinc	Surface water							X	X	
	Sediment							X	X	X
	Biota (fish)							X	X	
	Soil							X	X	
Selenium	Soil									
Di-n-butyl-phthalate	Soil						X			
Fluoranthene	Soil						X			
Pyrene	Soil						X			
Benzo(a)anthracene	Soil							X	X	
Chrysene	Soil							X	X	
bis(2-ethylhexyl)phthalate	Soil			X						
Benzo(b)Fluoranthene	Soil							X	X	
Benzo(k)fluoranthene	Soil							X	X	



TABLE 6-1 (CONTINUED)

**CHEMICALS OF CONCERN SELECTION CRITERIA**  
**SITE 12**  
**NAVAL AMPHIBIOUS BASE - LITTLE CREEK**  
**VIRGINIA BEACH, VIRGINIA**

Constituent	Media	Selection Criteria Not Met						Retained for Evaluation		
		Detection Frequency	Fact. Unavail. Bkg. Const.	Common Laboratory Contaminant	Federal & State Standards	Health Advisory	Risk Based Screening Levels	Detection Frequency	Criteria Met	Detected Otherwise/ Hist. Pres.
Benzo(a) pyrene	Soil							X	X	
Heptachlor	Soil							X	X	
4,4'-DDE	Soil						X			
4,4'-DDD	Soil						X			
4,4'-DDT	Soil							X	X	
Alpha-chlordane	Soil							X	X	
Gamma-chlordane	Soil							X	X	

"X" denotes satisfied criteria.

TABLE 6-2

**CHEMICALS OF CONCERN SELECTION CRITERIA  
SITE 13  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

Constituent	Media	Selection Criteria Not Met						Retained for Evaluation		
		Detection Frequency	Fact. Unavail. Bkg. Const.	Common Laboratory Contaminant	Federal & State Standards	Health Advisory	Risk Based Screening Levels	Detection Frequency	Criteria Met	Detected Otherwise/ Hist. Pres.
Acetone	Surface soil			X			X			
	Subsurface soil			X			X			
Ethylbenzene	Subsurface Soil				X	X	X			
	Ground water				X	X	X			
Xylene (total)					X	X	X			
					X	X	X			
Vinyl chloride	Ground water							X	X	
Carbon di-sulfide	Ground water	X		X			X			
Dichloro-ethane, 1,1-	Ground water	X					X			
Trichloro-ethene	Ground water							X	X	
Tetrachloro-ethene	Ground water							X	X	
Tetrachloro-ethane, 1,1,2,2	Ground water								X	
Toluene	Surface Soil						X			
	Ground water				X	X	X			
Chloro-benzene	Ground water								X	
Naphthalene	Subsurface soil							X	X	
	Ground water						X			
Methyl naphthalene, 2-	Surface soil		X							
	Subsurface soil							X		
	Ground water		X							
Pentachloro-phenol	Surface soil							X	X	
	Subsurface soil							X	X	
	Ground water							X	X	
Bis (2-ethylhexyl) phthalate	Surface soil			X			X			
	Subsurface soil			X						
Acenaphthene	Surface soil	X					X			
	Ground water	X					X			
Dibenzofuran	Surface soil							X	X	
	Ground water	X								
Fluorene	Surface soil	X					X			
	Ground water	X					X			

TABLE 6-2 (CONTINUED)

**CHEMICALS OF CONCERN SELECTION CRITERIA  
SITE 13  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

Constituent	Media	Selection Criteria Not Met						Retained for Evaluation		
		Detection Frequency	Fact. Unavail. Bkg. Const.	Common Laboratory Contaminant	Federal & State Standards	Health Advisory	Risk Based Screening Levels	Detection Frequency	Criteria Met	Detected Otherwise/ Hist. Pres.
Phenanthrene	Surface soil							X		
Anthracene	Surface soil						X			
Fluoranthene	Surface soil						X			
Carbazole	Surface soil						X			
Pyrene	Surface soil						X			
Butylbenzyl phthalate	Surface soil			X			X			
Benzo (a) anthracene	Surface soil							X	X	
Chrysene	Surface soil						X			
Benzo (b) fluoranthene	Surface soil							X	X	
Benzo (k) fluoranthene	Surface soil						X			
Benzo (a) pyrene	Surface soil							X	X	
Indeno (1,2,3-pyrene)	Surface soil							X	X	
Dibenzo (a,h) anthracene	Surface soil						X			
Benzo (g,h,i) perylene	Surface soil							X	X	
Dichloro-benzene, 1,4-	Ground water				X	X				
Dichloro-ethene, 1,2-	Ground water							X	X	
Manganese	Ground water							X	X	
Benzene	Subsurface soil							X	X	
1,1,1 trichloroethene	Subsurface soil									

"X" denotes satisfied criteria.

### 6.2.1 Criteria and Standards

In conjunction with the frequency evaluation, a comparison of contaminant concentrations with available State and Federal standards, criteria, and site-specific and/or regional background information was conducted. Criteria are usually nonenforceable guidelines while standards are enforceable regulations. Chemical concentrations detected in groundwater samples for all sites were compared to site background concentrations for groundwater. These background concentrations are presented in Section 5.0. Criteria and standards considered during this RA are presented below.

**Maximum Contaminant Levels (MCLs)** - MCLs are Federal enforceable standards for public water supplies promulgated under the Safe Drinking Water Act. MCLs have been adopted for public drinking water systems and apply to drinking water supplies consumed by a minimum of 25 persons. A MCL's basis incorporates the prevention of human health effects associated with a 70-year lifetime exposure by a 70 Kg adult consuming 2 liters of water per day. The technical and economic feasibility of removing the constituent from a public water supply also factors into these limits.

**Ambient Water Quality Criteria (AWQCs)** - AWQCs are Federal nonenforceable regulatory guidelines and are primarily used to assess acute and chronic toxic effects on aquatic organisms. They may also be used for identifying the potential for human health risks. AWQCs consider acute and chronic effects in both freshwater and saltwater aquatic life, and potential carcinogenic and noncarcinogenic health effects in humans from ingestion of both water (2 liters/day) and aquatic organisms (6.5 grams/day fish). In addition, AWQCs for human health are based on either the consumption of water (2 liters/day) and aquatic organisms, or the consumption of aquatic organisms only. The AWQCs for the protection of human health for potential carcinogenic substances are based on the USEPA's specified incremental cancer risk range of one additional case of cancer in an exposed population of 10,000,000 to 100,000 persons (i.e., the  $10^7$  to  $10^5$  range).

**State of Virginia Water Quality Standards for Groundwater and Surface Water (WQSS)** - WQSS consist of narrative statements and numeric limits which describe the water quality necessary to meet and maintain reasonable and beneficial uses such as swimming and other water-related recreation, the public water supply, and the propagation and growth of aquatic life.

**Health Advisories (HAs)** - The USEPA, Office of Drinking Water developed HA guidelines for non-regulated constituents in drinking water. These guidelines consider acute and chronic toxic effects in children who consume 1 liter of water per day or in adults (assumed body weight of 70 kg) who consume 2 liters of water per day. Health Advisories are generally available for acute (1 day), subchronic (10 days), and chronic (longer-term) exposure scenarios. These guidelines are designed to consider only threshold effects and, as such, are not acceptable levels of potential human carcinogens.

**USEPA Region III Risk Based Concentration Tables** - USEPA Region III has developed Risk Based concentrations (RBC's) of chemicals to screen sites for potential impacts to human health. Simply put the RBC's are risk assessments run in reverse using standard conservative default assumptions. The USEPA Region III RBC tables consider residential and industrial soil exposure, fish ingestion, inhalation exposure and tapwater ingestion. In addition soil screening levels are provided for transfers of

contaminants from soil to air and groundwater. The RBC's are used in the COC screening process involving a comparison of the maximum concentration of each contaminant to either residential soil concentration or threat to groundwater soil concentration.

Currently, the only enforceable standards are the Federal MCLs and State of Virginia WQSs for groundwater and surface water. Other regulatory guidelines (as previously specified) are used for comparative purposes to infer potential health risks and environmental impacts.

#### 6.2.2 Environmental Media

The following sections discuss the selection of COCs for human health at each site in each applicable environmental media. In addition to the above described selection criteria, several compounds were not considered because:

- they occur naturally in the environment, especially in brackish water;
- they are typical laboratory contaminants; or,
- detected concentration ranges were less than U.S.EPA, Region III defined screening levels that produce a 0.1 Hazard Index (HI) or  $1 \times 10^{-6}$  Incremental Cancer Risk (ICR). (USEPA Region III-Based Concentrations: R.L. Smith, 10/20/95).

The inorganics calcium, magnesium, potassium, and sodium are considered as naturally occurring chemicals, and were not evaluated. COC compounds with unavailable carcinogenicity or toxicity factors were evaluated qualitatively and compared to standards and criteria if available. Appendix K contains complete tables of the COCs evaluated at each site by media.

##### 6.2.2.1 Site 12

Site 12, the Exchange Laundry Waste Disposal Area, consists of a storm sewer line and drainage canal. This site previously received dry cleaning wastes from the former laundry. During this investigation, three environmental media were sampled: sediment, surface water and groundwater. Table 6-1 provides a summary of the COC selection and evaluation process for all media at Site 12.

##### Groundwater

A total of ten groundwater samples were collected during the RI/FS and the SRI. COCs identified include volatiles such as vinyl chloride, 1,2-dichloroethene, chloroform, trichloroethene, and tetrachloroethene based on exceedances of the tapwater RBCs of EPA Region III, federal MCLs and their frequency of detection; pesticides such as aldrin, heptachlor, alpha chlordane and gamma chlordane were retained based on their frequency of detection and exceedances of the tapwater RBCs; and inorganics such as aluminum, arsenic, barium, cadmium, chromium, cobalt, iron, lead, manganese, nickel, vanadium, and zinc. Aluminum, barium, chromium, cobalt, vanadium and zinc were retained as COCs due to their

occurrence in other site media while the remaining inorganic COCs were retained due to exceedances of federal MCL's, tapwater RBCs or Virginia Groundwater Quality Standards.

### Surface Water

A total of nine surface water samples were collected during RI/FS and the SRI. Eighteen COCs were identified including 15 inorganics and 3 volatiles organic compounds.

Inorganics retained as COCs include aluminum, arsenic, barium, cadmium, beryllium, chromium, cobalt, iron, lead, manganese, mercury, nickel, vanadium, and zinc. Compounds readily occurring naturally, such as in or near brackish water, included calcium, magnesium, potassium and sodium were not retained as COCs. Volatiles retained as COCs include 1,2-dichloroethene, trichloroethene, and tetrachloroethene. Toluene was detected below Federal or State water quality guidelines while acetone and toluene were detected below the USEPA Region III RBC screening levels.

Aluminum, barium, cadmium, cobalt, copper, vanadium, and zinc were retained for evaluation due to their presence in other exposure media including sediment. While arsenic, chromium, iron, lead, manganese, mercury and nickel exceed one or more of the screening criteria.

Common laboratory contaminants include acetone and 2-butanone were not retained because they did not exceed the COC selection criteria.

### Sediment

This addendum to the Baseline Risk Assessment uses the nine sediment samples collected during both the original and supplemental RI/FS. Nineteen COCs were identified, including 15 inorganics and 4 volatiles, after comparing their maximum concentration to the residential soils concentration on the USEPA Region III Risk-Based Concentration Table and their occurrence in other site media.

Inorganics retained as COCs include aluminum, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, vanadium, and zinc.

Volatiles retained as COCs include 1,2-dichloroethene, toluene, trichloroethene, and tetrachloroethene. While xylene was detected below Federal or State water quality guidelines and acetone, toluene and xylene were detected below USEPA Region III RBC screening levels.

A common laboratory contaminant and decontamination solvent, acetone was not retained.

Compounds readily occurring naturally, such as in or near brackish water, included calcium, magnesium, potassium and sodium were not retained as COCs.

## Fish

Fish concentration values for Site 12 were calculated using the constituents detected in surface waters. The concentrations for inorganics are based on unfiltered samples. A total of nine surface water samples were collected during the RI and SRI. Fish concentrations were calculated based on the maximum detected concentration of each applicable compound and a representative bioconcentration factor (BCF) for that compound. The BCFs used provide a measure of the extent of chemical partitioning at equilibrium between fish tissue and water medium. Six inorganic COCs were identified for subsequent evaluation.

Inorganics retained as COCs in the evaluation were arsenic, beryllium, copper, mercury, and zinc.

One volatile compound was retained as a COC, tetrachloroethene.

Aluminum, barium, cobalt, iron, manganese, and vanadium were not retained as a COC due to unavailable bioconcentration factor.

1,2-dichloroethene, trichloroethene, cadmium, chromium, lead, and nickel were not retained as COCs because they had concentrations below USEPA Region III RBC screening levels.

## Subsurface Soils

This addendum to the Baseline Risk Assessment evaluated six subsurface soil samples collected from 0-2 feet to the top of the water table during the supplemental RI/FS. Twenty-five COCs were identified including volatiles such as toluene and tetrachloroethene based on their exceedance of the residential USEPA Region III RBC values; semivolatiles such as chrysene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, and benzo(a)pyrene due to their exceeding the USEPA Region III RBC values; pesticides such as heptachlor, 4-4'DDT, alpha chlordane, and gamma chlordane were retained as COCs based on their exceeding the USEPA Region III residential RBC; and inorganics such as aluminum, arsenic, barium, beryllium, chromium, cobalt, copper, iron, lead, nickel, manganese, selenium, vanadium, and zinc were retained based on their occurrence in other media and exceedances of USEPA Region III RBC levels.

### 6.2.2.2 Site 13

Site 13, the Public Works PCP Dip Tank and Wash Rack, consists of a wash rack and storage area encompassing approximately 30,000 ft<sup>2</sup>. This area previously contained a dip tank for treating wood with PCP, associated drying racks, and a storage area and wash rack. During this investigation, three environmental media were sampled, including surface soil, subsurface soil and groundwater. Table 6-2 provides a summary of the COC selection and evaluation process for all media at Site 13.

## Surface Soils

A total of six surface soil samples from 0-6 inches, were collected during the original RI/FS and the supplemental RI/FS. Nine COCs were retained from the semi-volatile analyses, including dibenzofuran and 2-methyl naphthalene because of their frequency of detection and available toxicity reference values, and benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, benzo(g,h,i)perylene, pentachlorophenol, and phenanthrene due to their exceedance of the USEPA Region III RBC values.

Compounds that were detected below USEPA Region III RBC screening levels included acetone, toluene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, carbazole, pyrene, butylbenzyl phthalate, chrysene, bis(2-ethylhexyl)phthalate, benzo(k)fluoranthene, and dibenzo(a,h)anthracene.

## Subsurface Soils

A total of nineteen subsurface soil samples from below 6 inches to the top of the water table were collected at Site 13. Eight COCs were identified from this sampling effort.

The volatile organic compound benzene, the semi-volatiles evaluated are pentachlorophenol, naphthalene and 2-methyl naphthalene. The COCs identified were evaluated for possible transport and mobility to the groundwater, which is discussed in Section 6.1.3.3.

Chemicals detected in the subsurface soils were also evaluated with respect to a possible future scenario in which the subsurface soils are brought to the surface and made available for direct contact. **Table 6-2** provides a summary of the COC selection and evaluation process for the future scenario of the subsurface soils. A total of eight COCs were identified. The COCs include volatile organic compound benzene due to it being a Class A carcinogen, the semi-volatiles retained as COCs include pentachlorophenol due to its historical use at the site and its exceeding the USEPA Region III RBC value, and 2-methyl naphthalene, and the inorganics beryllium and chromium for exceeding the USEPA Region III RBC, arsenic due to it being a Class A carcinogen and antimony, barium and manganese for being acceptable toxicity values and meeting the frequency of detection requirement.

The common laboratory contaminants include acetone and bis(2)ethylhexphthalate were not retained because they did not exceed the USEPA Region III RBCs.

Compounds that were detected below USEPA Region III RBC screening levels or Federal and State water quality guidelines included acetone, ethylbenzene, and xylene.

## Groundwater

A total of twenty-one groundwater samples were collected at Site 13. Nine COCs were identified including 6 volatiles, 2 semi-volatiles, and 1 inorganics.



Volatile organics retained as COCs include vinyl chloride, 1,2-dichloroethene, trichloroethene, tetrachloroethane, 1,1,2,2- tetrachloroethane, and chlorobenzene because of their exceeding Federal MCLs or the USEPA Region III tapwater RBC. Semi-volatiles retained as COCs include pentachlorophenol and naphthalene because it occurred in the other site media and the inorganic evaluated is manganese because it exceeded the Virginia groundwater standard and the USEPA Region III tapwater RBC.

Compounds that were detected below Federal or State water quality guidelines and not retained as COCs included toluene, ethylbenzene, xylene, 1,4-dichlorobenzene, and fluorene.

Compounds that were detected below USEPA Region III RBC screening levels and not retained as COCs included, ethylbenzene, xylene (total), carbon disulfide, toluene, acenaphthene, bis(2)ethylphthalate, and 1,1-dichloroethane.

### **6.3 Exposure Assessment Pathways and Inputs**

Exposure assessments address each potential exposure pathway in surface soil, subsurface soil, groundwater, surface water, and sediment. To determine whether human exposure may occur at a site without remedial action, an assessment identifying potential exposure pathways and receptors was conducted. The following four elements were considered to determine whether a complete exposure pathway was present:

- a source and mechanism of chemical release;
- an environmental transfer medium;
- a local exposure route; and,
- a receptor at the exposure endpoint.

The exposure scenarios discussed herein have been developed in accordance with the USEPA's Reasonable Maximum Exposure (RME). Relevant equations for assessing intakes and exposure factors were obtained from the Exposure Factors Handbook (USEPA, 1988), Dermal Exposure Assessment: Principles and Applications - Interim Report (USEPA, 1992), Risk Assessment Guidance for Superfund Volume I, Human Health Evaluation Manual (Part A) Interim Final (USEPA, 1988), and the Risk Assessment Guidance for Superfund Volume II Environmental Evaluation Manual Interim Final (1989).

#### **6.3.1 Exposure Setting Characteristics**

The climate in the Virginia area is classified as oceanic moderated by the proximity of the Atlantic Ocean. The average temperatures are approximately 42°F in the winter and 77°F in the summer. Rainfall is distributed throughout the year and long periods of drought seldom occur. The average annual precipitation is approximately 45 inches.

### **6.3.2 Identification of Human Receptors**

Potential human receptors identified for these sites are discussed in the following sections for the current and future land-use scenarios.

#### **6.3.2.1 Current Land-Use**

Current land-use receptors identified for these sites, based on a conservative approach, include site maintenance and base employees, base and local area residents (children, ages 0-6 and adults) who may trespass in areas associated with the sites, trespassers who may take up residence adjacent to the waterways flowing next to the sites, and recreational users who may exercise, use currently existing recreational facilities on-site, or fish in the waterways around the site.

#### **6.3.2.2 Future Land Use**

The future land-use receptors identified for these sites are based upon the future development of the area into a residential neighborhood. Therefore, receptors consist of local residents (children, ages 0-6, and adults) who would reside permanently on the sites for surface soil, surface water, sediment, and fish ingestion exposure pathways. However, for the groundwater exposure pathway, future land-use receptors would be exposed only as recreational/trespassers (children, ages 0-6, and adults) with exposure frequencies of 14 days/year for children, and 28 days/year for adults. The receptor evaluated in this scenario is a child and/or adult who would tap into the shallow aquifer, and use the groundwater for contact. This future scenario is a conservative approach for the groundwater exposure pathway since the available shallow aquifer is not potable for drinking water, and the future water supply source will be city water. In addition, sites with subsurface soil samples were considered as a future surface soil exposure pathway. This exposure route was evaluated for a possibility of the subsurface soils being brought to the surface and made available for contact.

### **6.4 Fate and Transport**

#### **6.4.1 Potential Migration Pathways**

This section identifies the potential migration routes of COCs at the sites. These migrations pathways were identified through an evaluation of the analytical results and known site characteristics.

##### **6.4.1.1 Surface Soil**

The factors which control contaminant migration through soil depend on the chemical and physical nature of the contaminants and the soil. Some of the factors which influence the migration of chemicals in soil include pH, oxidation/reduction reactions (Eh), particle size distribution, pore size distribution, lime content, content of organic matter, concentration of ions or salts, aerobic and anaerobic conditions, presence or absence of hydrous oxides, vegetative cover, topography, and climate.

#### 6.4.1.2 Subsurface Soil/Groundwater

Contaminants which come into contact with subsurface soils and groundwater can migrate off-site during precipitation periods as interflow and under the influence of groundwater flow. Contaminant migration through interflow depends on the chemical nature of the contaminant, chemical and physical nature of the subsurface soils, and chemical nature of the rainfall. Due to the relatively small number of subsurface soil samples, a detailed fate and transport model can not be utilized from the data available for interflow. In this analysis, all interflow migrate into the groundwater table. This worst case scenario was utilized in combination with the individual contaminant's chemical and physical characteristics to determine its potential of migrating into the groundwater. Section 6.1.3.4 contains a detailed description of the migration analysis conducted.

Migration through groundwater depends on the chemical nature of the contaminant and the chemical and physical nature of the aquifer. Groundwater flow velocity (a function of hydraulic gradient and conductivity), groundwater chemistry, and the chemical make-up of the aquifer affect contaminant migration. Due to the relatively small number of groundwater wells and subsequent samples, a detailed fate and transport model can not be utilized from the data available for groundwater transport.

#### 6.4.1.3 Surface Water/Sediment

Migratory pathways associated with surface water and sediment include the transport of contaminants via surface water movement, and adsorption/desorption of contaminants to sediments. The adsorption/desorption process, from surface water to sediments, can create contaminant "sinks" in which benthic macroinvertebrates and water column organisms (i.e., fish) may be subject to contaminant exposure via the food chain. Adsorption/desorption mechanisms involve both chemical and biochemical reactions. As chemicals desorb from sediment, they are then available for uptake to organisms in the water column; the higher the solubility of the chemical, the more bioavailable it is to aquatic organisms, but the less it tends to bioaccumulate.

### 6.4.2 Chemical Fate and Transport

This section discusses the potential release and migration of COCs between or within media. The potential for a chemical to migrate spatially and persist in environmental media is important in the estimation of exposure.

The distribution relationships for a chemical between air, water, and soil can be expressed as a series of equilibrium constants. By utilizing the physiochemical properties of a contaminant, the expected environmental distribution and ultimate environmental fate was evaluated. Based on the COCs identified at each site and the concentrations of each organic COC, the subsurface soil concentrations were evaluated to determine if these concentrations may leach into the groundwater medium, thus, increasing the detected groundwater concentrations to be utilized for the human health RA.

**Table 6-3** presents select physical and chemical properties associated with the organic COCs identified in subsurface soils for sites 12 and 13, including specific gravity, vapor pressure, water solubility,

TABLE 6-3

**PHYSICAL AND CHEMICAL PROPERTIES OF ORGANIC COCs  
DETECTED IN SUBSURFACE SOILS  
NAB LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

COCs Subsurface Soil	Vapor Pressure, P, (mm Hg) @ 20°C	Water Solubility, S (mg/l) @ 20°C	Octanol/Water Coefficient (K <sub>ow</sub> )	Adsorption Coefficient (K <sub>oc</sub> )	Specific Gravity (g/cm <sup>3</sup> ) @ 20°C
Toluene	2.81E+01	5.35E+02	3.00E+03	300	0.867
Tetrachloroethene	1.78E+01	1.50E+02	759	364	1.626
Benzo(a)anthracene	2.20E-08	5.70E-03	1.38E+06	2.0E+05	—
Chrysene	6.30E-09	1.80E-03	4.1E+05	2.0E+05	1.274
Benzo(b)fluoranthene	5.00E-07	1.40E-02	1.15E+06	5.5E+06	—
Benzo(k)fluoranthene	5.10E-07	4.30E-03	1.15E+06	5.5E+06	—
Benzo(a)pyrene	5.60E-09	1.20E-03	1.15E+06	5.5E+06	—
Heptachlor	3.00E-04	1.80E-01	2.60E+04	1.20E+04	1.57
4,4'-DDT	5.50E-06	5.00E-03	2.43E+05	3.9E+06	—
alpha-chlordane	1.00E-05	5.60E-01	3.00E+05	1.4E+05	—
gamma-chlordane	1.00E-05	5.60E-01	3.00E+05	1.4E+05	—
Naphthalene	4.6E-04	31.7	1.93E+03	940	1.152
Pentachlorophenol	1.03x10 <sup>-4</sup>	14	6	41	1.978

## Sources:

1. Swan et al. (1983)
2. CRC Handbook (1984)
3. Merck & Co., Inc. (1968)
4. Verscheuren, K. (1983)
5. Aquatic Fate Process Data for Organic Priority Pollutants, USEPA (1982)

## Notes:

1. Calculations completed by following equations:

a.  $\ln(K_{oc}) = \ln(K_{ow}) - 0.7301$

(From Briggs, G.G. (1973)

b.  $\ln(S) = -1.7288 \ln(K_{oc}) - 0.01 * ((\text{molecular weight} * P_v) - 25) + 15.1621$

(From Swan et al. (1980)

octanol/water partition coefficient, soil/sediment adsorption coefficient, degradation, and Henry's Law constant. When literature values were unavailable, approximation methods were utilized to calculate values. Table 6-4 then presents a summary of the behavior characteristics that control the environmental fate and transport of classes of organic compounds of concern at sites 12 and 13. A discussion of the environmental significance of each of these properties follows.

- The vapor pressure of a liquid or solid is the pressure of the gas in equilibrium with the liquid or solid at a given temperature. It indicates the volatilization rate of a chemical, evaporative loss. This value is significant at environmental media interfaces. When a liquid or solid reaches equilibrium with the surrounding air, it stops volatilizing or evaporating. Chemicals with higher vapor pressures enter the atmosphere quicker than chemicals with lower vapor pressures. Volatilization produces significant losses of volatiles in surface soils and surface waters. However, it does not produce significant losses in groundwater or subsurface soils, until they are exposed to the atmosphere, i.e. showering.
- Water solubility is the maximum concentration that a chemical reaches in water before a two phase (solid/liquid or liquid/liquid) system results. This value represents the upper limit of a chemical's dissolved concentration in water at a given temperature and pressure. This value helps determine a chemical's rate of being dissolved and potentially leached from soil by infiltration. Usually highly soluble chemicals leach quicker than low solubility chemicals. Solubilities are affected by the natural composition of waters, which can vary greatly. Natural variability in water's pH, hardness, and humic and fulvic acid content, and the presence of other chemicals may increase or decrease the solubility of a chemical.
- The octanol/water partition coefficient ( $K_{ow}$ ) represents the equilibrium partitioning of chemicals between octanol and water.  $K_{ow}$  values have been found to have a linear relationship with the uptake of a chemical by animal and human receptor's fatty tissues. This value also assists in characterizing the sorption of compounds in organic soils.
- The soil/sediment coefficient ( $K_{oc}$ ) is defined as the ratio of adsorbed chemical per unit of organic carbon to the concentration of the chemical in solution. The value determines the tendency of a chemical to adsorb onto organic carbon or to dissolve into solution.  $K_{oc}$  values are inversely proportional to a chemical's water solubility. This parameter also infers the relative rates at which the more mobile chemicals are transported in the aqueous media. Inorganics are relatively immobile in the environment and preferentially bind with soil. Therefore, these compounds are not subject to aqueous transport to the extent compounds with high solubilities are.
- A compound can degrade from a variety of processes, including photolysis, hydrolysis, and biodegradation. Photolysis is the decomposition of a compound into simpler units as a result of adsorbing one or more quanta of radiation (e.g., energy from sunlight). This is a surface process only, since it requires sunlight and may play an initial step in

TABLE 6-4

**MOBILITY INDEX OF ORGANIC COCs  
DETECTED IN SUBSURFACE SOILS  
NAB LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

COCs in Subsurface Soil	Vapor Pressure, P, (mm Hg) @ 20°C	Water Solubility, S (mg/l) @ 20°C	Adsorption Coefficient (log K <sub>oc</sub> )	Mobility Index (MI)	Comments
Toluene	2.81E+01	5.35E+02	300	1.70	Very Mobile
Tetrachloroethene	1.70E+01	1.50E+02	364	0.86	Very Mobile
Benzo(a)anthracene	2.20E-08	5.70E-03	2.00E+05	-15.2	Very Immobile
Chrysene	6.30E-09	1.80E-03	3.00E+05	-16.2	Very Immobile
Benzo(b)fluoranthene	5.00E-07	1.40E-02	5.50E+06	-14.9	Very Immobile
Benzo(k)fluoranthene	5.10E-07	4.30E-03	5.50E+06	-15.4	Very Immobile
Benzo(a)pyrene	5.60E-09	1.20E-03	4.40E+06	-17.9	Very Immobile
Heptachlor	3.00E-04	1.80E-01	1.20E+04	-8.35	Immobile
4,4'-DDT	5.50E-06	5.00E-03	3.90E+06	-14.2	Very Immobile
alpha-chlordane	1.00E-05	5.60E-01	1.40E+05	-10.4	Very Immobile
gamma-chlordane	1.00E-05	5.60E-01	1.40E+05	-10.4	Very Immobile
Naphthalene	4.60E-04	31.7	940	-4.81	Immobile
Pentachlorophenol	1.03x10 <sup>-4</sup>	14	41	-3.41	Slightly Immobile

## Sources:

1. Laskowski (1983)
2. Ford et al. (1984)

the degradation process, but is not considered a major degradation process at these sites.

Hydrolysis is defined as the chemical reaction in which water reacts with another substance to form two or more substances. This process can be very important in the soil-water system in degrading certain types of compounds, including alkyl halides, chlorinated amides, and esters. The process can be catalyzed by the soil particles. Hydrolysis is potentially an important process at the sites, but the low concentration of compounds in the groundwater makes it difficult to quantify the contribution.

Biodegradation is any biologically induced structural change in an organic chemical. Biodegradation of organic molecules may be a very important process at the site. Numerous molecular fragments are susceptible to transformation through the action of microorganisms. An example of this type of reaction would be the transformation of PCE to increasingly simpler compounds such as TCE, DCE, DCA, vinyl chloride, and chloromethane. At the Naval Amphibious Base Little Creek (NABLC), the low concentrations of many compounds, such as benzo(a)pyrene, make it difficult to determine if it represents a primary source or degradation product.

- Oxidation is a chemical reaction which involves the removal of electrons from an element or compound. Conversely, electrons are added to chemical substrates in reduction reactions. Both oxidation and reduction reactions are environmentally significant in that they influence the mobility and fate of chemicals in environmental matrices. Oxidized and reduced forms of the same element or compound may also have totally different chemical, ecological and toxicological properties. For example, hexavalent chromium (i.e. Cr(VI)) is an oxidized valence state of chromium that is generally highly toxic whereas trivalent chromium (i.e., Cr(III)) is a reduced form of chromium that is generally less toxic. Oxidation-reduction reactions are commonly referred to as "redox" reactions.
- Specific gravity represents the ratio of a given volume of a pure chemical at a specified temperature to the weight of the same volume of water at a given temperature. Specific gravity determines whether a constituent tends to float or sink in water if present as a pure compound or at a concentration exceeding its water solubility. It should be noted that stratification of a chemical in water (i.e., sinking or floating) is expected only when the chemical is present at high concentrations, near its maximum solubility. As an example at the site, if present at a high enough concentration in the groundwater, benzene or acetone with a specific density less than one, would float whereas PCP, with a specific density of 1.98, would sink. There is some evidence, however, to indicate the specific density of the compounds in question is of importance to the facility due to the limited, low concentrations of chemical compounds detected in the monitoring wells. No non-aqueous phase liquid (NAPL), either dense non-aqueous phase liquid (DNAPL), or light non-aqueous phase liquid (LNAPL), has been observed or suspected based on the analytical results.

- The percent organic carbon content is the ratio of the weight of organic carbon in a sample to the total weight of the sample, and is typically measured for soil samples. This is an important site-specific parameter for the prediction of potential leachability or adsorption of a COC as it passes through an organic rich layer, such as peat or compost, as well as any retardation of the compound as it migrates through the aquifer. The distribution coefficient, a measure of the soil's capacity to adsorb the compound from solution onto a soil particulate, can be developed by relating the  $K_{oc}$  value of a compound, the percent organic carbon in the soil, and other site specific conditions. Total Organic Carbon (TOC) was analyzed for all the soil and sediment samples collected at NABLC sites. This is a relatively high range illustrating the higher clay content, and lesser chemical leachability of the soils. Soils at Site 13 had a TOC of more than 1% at all locations.
- Soil particle size can be used to distinguish between soil types present at the sites and to obtain a rough estimate of the amount of percolation that may occur through the soil column. When a soil is composed largely of sand, extensive percolation of precipitation can occur which may increase the leaching of compounds from contaminated soils. At the facility, the topographically higher areas contain the relatively porous sand. This is evident in the cross-sections presented in Section 4.0. Precipitation enters the topographic high areas and recharges the underlying sand. Groundwater flow maps presented in Section 4.0 illustrate the flow pattern from these high areas which may leach constituents of concern from the sand into the groundwater. The lack of constituents in the soil at significant levels suggests that this process is not a major concern.
- Cover material on the site affects both the volatilization of COCs from the soil and the amount of precipitation that can percolate through the vadose zone. Vegetative cover can act as a cap, reducing volatilization from the soils. Percolation can be reduced by the uptake of water in plant roots. Vegetative covers can also limit the extent of wind blown dust and surface runoff as routes of contamination migration, as well as the source of natural soil organic material.

#### 6.4.2.1 Volatile Organic Compounds

##### a) Chlorinated Volatiles

Chlorinated volatile organic compounds (VOCs) such as tetrachloroethene is commonly used as a solvent and degreaser in a variety of industrial processes and in the dry cleaning industry. Chlorinated VOCs are generally mobile and not very persistent in the environment, principally due to their high volatility, low adsorption to soils, inability to substantially bioaccumulate and high aqueous solubility. Because of these characteristics, the primary fate and transport mechanisms affecting VOCs are volatilization into the air and migration in groundwater. The high volatility of VOCs limits, somewhat, the extent to which surface water and/or groundwater transport will be a major transport process, because the VOCs may volatilize out of unconfined or partially confined waterbodies. Due to the high mobility of chlorinated VOCs, a decrease in their soil concentrations is anticipated with time, as long as there is no additional



input of these compounds. The chlorinated VOCs also tend to undergo degradation reactions in anaerobic soil systems. The degradation reactions involve the progressive loss of chlorine ions from the molecular structure, resulting in stepwise dechlorination. (Merck, 1990).

At site 12 the only chlorinated VOC retained as a COC in subsurface soil was tetrachloroethene. Based on the fact that tetrachloroethene was the only chlorinated VOC retained as a COC in subsurface soil and TCE 1,2 DCE, and vinyl chloride were detected in the site groundwater it is likely that these are degradation products of PCE not a new source of additional compounds.

#### b) Non-Halogenated Volatiles

Only two non-halogenated VOC's, toluene (Site 2) and Benzene (Site 13) were identified as COC's from the subsurface soil. These non-halogenated VOCs are also widely used as industrial solvents, and benzene, may also occur in petroleum products and petroleum combustion exhaust fumes (Merck, 1990).

Compounds of this subclass generally are mobile and not very persistent in the environment due to their high volatility, low to moderate (ethylbenzene only) adsorption to soils, low bioaccumulation potential and high water solubility. The environmental behavior of the non-chlorinated VOCs differs from the chlorinated VOCs primarily in that the non-chlorinated compounds are subject to more rapid biodegradation/ biotransformation processes that further contribute to a low persistence in the environment.

#### 6.4.2.2 Semi-Volatile Organic Compounds

Several semivolatile organic compounds from three generalized classes of semivolatile compounds have been identified as contaminants of potential concern at Sites 12 and 13. Each of these three classes will be discussed in the subsections that follow with emphasis placed upon the contaminants of potential concern.

##### (a) Polycyclic Aromatic Hydrocarbons (PAHs)

Six PAHs (benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, 2-methylnaphthalene) were identified as compounds of potential concern. PAHs are typical components of asphalt, fuels, oils and greases (Merck, 1990).

PAHs are persistent and generally immobile in soil matrices under normal environmental conditions. This is primarily due to their low aqueous solubility and resistance to photolytic, oxidative and hydrolytic degradation, and their high affinity for adsorption to organic matter and soil particles. However, in the presence of highly mobile organic compounds (i.e., VOCs or phenolic compounds) which can act as cosolvents, the mobility of PAHs in soils can be greatly enhanced. PAHs can be degraded by microbial populations, however, this is generally a slow process in the environment. Among PAHs, naphthalene is relatively more mobile in the environment due to its lower adsorptive affinity and higher aqueous solubility in comparison to most PAHs. The carcinogenic PAHs tend to be high molecular weight compounds which are less mobile in the environment and more likely to bind to soil particles. Some of

the PAHs may exhibit substantial bioaccumulation (i.e., fluoranthene and fluorene); however, this is usually a ephemeral effect since most organisms have the ability to metabolize these compounds.

(b) Phenolics

One phenolic compound (pentachlorophenol) was identified as compounds of potential concern in Site 13 soils. Phenolics are high-volume industrial chemicals with multiple uses, one of which is as a wood preservative (Merck, 1990). Phenolic compounds are also formed in decaying organic matter, such as decaying leaves or logs.

Pentachlorophenol exhibits a relatively reduced aqueous solubility, moderate affinity for organic matter and soil particles, and a tendency to bioaccumulate in aquatic organisms. Hydrolytic and photolytic reactions, are thought to occur, but only at slow rates under special conditions.

c) Pesticides

Pesticides are commonly used in agriculture as well as in commercial and residential areas to control insect populations. (Merck, 1990).

Pesticides are generally persistent in the environment, primarily due to their resistance to degradation, low aqueous solubility and volatility, ability to substantially bioaccumulate in aquatic organisms and very high adsorptive affinity for soils and organic matter. They are typically highly resistant to biodegradation and when it does occur, it is a very slow process. Primarily as a result of their very high adsorption to soils, pesticides are essentially immobile in soil matrices under normal environmental conditions. However, in the presence of highly mobile organic cosolvents (i.e., VOCs and phenolic compounds), the mobility of pesticides in soil can be greatly enhanced.

#### 6.4.2.3 Inorganic Compounds

Unlike the organic compounds discussed in preceding sections, the metals are difficult to discuss in terms of behaviorally similar groups. Additionally, many of the fate and transport mechanisms that may be important for organic compounds have little impact on the metals. Volatilization, for example, only applies to a select few metals or metallic compounds (e.g., Hg, some organo-metallic compounds), and then under special conditions. Photolysis is also of negligible importance to the environmental behavior of metals and most metallic compounds. The environmental behavior (i.e., the low temperature geochemistry) of the metals has been widely studied and the characteristics of individual metals are generally better understood than those of individual organic compounds. On the other hand, it is sometimes difficult to distinguish between naturally-occurring and introduced metals, particularly in the case of geochemical major (Al, Ca, Fe, Mg, K, and Na) and minor (Ba and Mn) elements.

The most important factors controlling metal fate and transport are solubility, redox behavior, aqueous speciation, and sorption behavior, all of which are functions of the ambient geochemical environment. As mentioned above, volatilization and photolysis are of limited importance. Biotransformation processes can be important for some metals (e.g., Hg, As) under certain environmental conditions. All metals are,

to variable extents, subject to cation-exchange reactions with minerals present in the environment. The extent to which cation-exchange occurs is dependent on the mineral species present and on pH, as well as on the characteristics of individual metals.

The mobility of metals within environmental matrices depends upon numerous factors such as the relative stabilities of individual valence states (which are element-specific), oxygen content, pH and Eh conditions, and the presence of available complexing agents. The expected predominant dissolved species or minerals of the metals in aqueous systems usually can be deduced from geochemical equilibrium models expressed in Eh-pH diagrams. However, such predictions are highly speculative and therefore, they will not be attempted or presented here.

In general, metals have a high adsorptive affinity for inorganic mineral surfaces and organic matter. Adsorption, for most metals, is highly pH-dependent, with desorption generally more favored at low pH and sorption mechanisms dominating at higher pH conditions. However, the types of clays and their surface charges in relation to soil pH values, dictate whether sorption or desorption will occur. Additionally, chemical speciation determines the relative degree of adsorption among different species of a particular metal. Based on the data available for site soils, sorption is most probably a significant fate process for metals. The aerobic conditions in the surface water and shallow groundwater are likely to promote the precipitation of ferromanganese oxides and oxyhydroxides (probably nucleating on sand and soil grains) to which other metals will readily adsorb.

#### **6.4.3 Transport and Mechanisms of Migration**

Contaminants may migrate from a source area via a variety of mechanisms. The importance of a given mechanism is controlled by the specific physical, geochemical, climatic and hydrologic conditions at a given site as well as by the physicochemical characteristics of the contaminated media. In this section of the report, the following potential pathways for the fate and transport of contaminants of concern identified within the various matrices at Sites 12 and 13 will be considered:

- Migration of contaminants from potential source areas to environmental media.
- Percolation and migration of contaminants into groundwater.
- Migration of contaminants within surface water and sediments.
- Migration of contaminants into fish
- Migration of contaminants in air.

##### **6.4.3.1 Migratory Contaminants From Potential Source Areas to Environment Media.**

Contamination of Sites 12 and 13 has occurred in the past as a result of past industrial and raw material handling operations and spills. As a consequence of these activities, areas of contaminated subsurface soil remain on-site. Chemicals in the subsurface soil may migrate within and/or with the environment

in several ways. Potential sources that are contaminated subsurface soils may be transported into the groundwater by the percolation and/or gravity. Volatile contaminants may volatilize from contaminated soils and be emitted to the atmosphere and subsequently transported by prevailing winds. At both Sites 12 and 13 surface run-off and entrainment of contaminated soil particles are expected to be very minor mechanisms of migration because more than 75% of the property is paved and vegetated.

#### Percolation and Migration into Groundwater

Contaminants of concern present in soils may migrate into groundwater by the percolation of rainwater through contaminated soils. Incorporation of contaminants within this percolating groundwater may be through direct dissolution of contaminants from soil into the percolating water or by dissolution into more water soluble organic compounds already entrained within the percolating rainwater (i.e., cosolvent effects). Principal contaminant classes present on-site that may migrate via this potential pathway are discussed in the paragraphs that follow.

The volatile organic and phenolic compounds are characterized by medium to high aqueous solubilities and low adsorptive affinities for soils. Due to the permeable nature of the site soils in conjunction with these characteristics, incorporation into percolating rainwater with their eventual dissolution and transport in groundwater is expected to be a major environmental fate mechanism for these organic compounds. This is substantiated by the groundwater data, which indicated volatile and phenolic compounds in groundwater, some of which were also present in overlying on-site soils at elevated concentrations.

A quantitative value indicating a compound's potential susceptibility to transport based on physical/chemical values has been developed. This calculated value represents a compound's mobility index (MI). The MI assesses a compound's mobility based on relative transport between air, water, soil, and biota (organic carbon content of soil), using the compound's water solubility (S), vapor pressure ( $P_v$ ), and  $K_{oc}$  (Laskowski, 1983). Therefore, the use of MI applies primarily to the unsaturated zone. MI values may be calculated using Equation 6.1.

$$MI = \log [ (S \times P_v) / K_{oc} ] \quad \text{Equation 6.1}$$

Ford and Gurba provides the following scale for evaluating MI:

<u>Relative MI</u>	<u>Mobility Description</u>
MI > 5	Extremely mobile
0 < MI < 5	Very mobile
-5 < MI < 0	Slightly immobile
-10 < MI < -5	Immobile
MI < -10	Very immobile

**Table 6-5** provides MIs for the potential organic COCs found in subsurface soils.

Although PAHs, and pesticides are typically not readily transported through soil due to their generally low aqueous solubilities and high adsorptive affinities, cosolvent effects mediated by the more mobile

TABLE 6-5  
SUMMARY OF BEHAVIORAL CHARACTERISTICS THAT CONTROL  
ENVIRONMENTAL FATE AND TRANSPORT OF CLASSES OF ORGANIC COMPOUNDS

	<u>Aqueous Solubility</u>	<u>Volatility</u>	<u>Adsorptive Affinity</u>	<u>Biodegradation/ Biotransformation</u>	<u>Photolysis Susceptibility</u>	<u>Hydrolysis Susceptibility</u>	<u>Oxidation</u>	<u>Bioconcentration In Fish</u>
<u>VOLATILE ORGANIC COMPOUNDS (VOCs)</u>								
Halogenated VOCs	High	V. High	V. Low	Low	V. Low	V. Low	V. Low	V. Low
Non-halogenated VOCs	High to V. High	High to V. High	V. Low to Medium	High to V. High	V. Low	V. Low	V. Low	V. Low
<u>SEMIVOLATILE ORGANIC COMPOUNDS (BNAs)</u>								
Phenolic Compounds	Medium to High	Medium	Low to Medium	High	V. Low	Low	Medium	V. Low to Low
PAHs	Low	Low	High	Medium to High	Low	V. Low	Low	Low to Medium
<u>PESTICIDES</u>								
Chlorinated Pesticides	V. Low	V. Low	V. High	Low	Low	V. Low to Medium	V. Low	Low to V. High

volatile organic and phenolic compounds into the underlying groundwater. This is suggested by the soils data, which noted PAHs, and pesticides occurring in subsurface soils in association with the more mobile organic compounds.

The transport of metals into groundwater is a function of the solubility (and related leachability) of a given metal in a specific water mass under specific conditions. Transport of metals into groundwater may also occur, to some extent, with particulate phases to which the metals are adsorbed. In water-bearing zones, transport of particulates is principally limited to colloid-size (i.e., extremely small, generally defined as less than 0.7  $\mu\text{m}$  in diameter) particles, or particles smaller than the available pore space. Larger particles cannot pass through water-bearing zones because of their size (generally larger than pore space) and because the energy of the water that is slowly percolating through the ground is usually insufficient to carry particles larger than colloids in suspension.

The most complicated pathway for inorganic chemicals is migration in subsurface soils and groundwater. In these media, redox potential and pH play critical roles. **Table 6-5** presents an assessment of the relative inorganic environmental mobilities as a function of Eh and pH. It has been assumed the subsurface soils at Sites 12 and 13 have relatively neutral Eh and pH characteristics. Therefore, inorganics in these subsurface soils should be relatively immobile.

#### Migration of Contaminated Groundwater Off-Site

Groundwater that may become contaminated beneath Sites 12 and 13 as a result of overlying contaminated soil may migrate through subsurface aquifers, thereby spreading and dispersing the contaminants. Migration of contaminants in groundwater is controlled by two processes: advection and dispersion. Advection is the process by which dissolved contaminants are transported by the bulk motion of groundwater flow. Dispersion is the spreading of dissolved contaminants as they move with groundwater and results from two basic processes: molecular diffusion and mechanical mixing. Both advection and dispersion act on contaminants in solution. Contaminants associated with large solid phases generally are not transported by groundwater, however some transport of very fine particles (i.e., colloids) may occur.

Based upon physicochemical characteristics, the volatile organic compounds and phenolic compounds would be expected to migrate the farthest, primarily due to their high aqueous solubilities and low adsorptive affinities. However, for the PAHs, and pesticides, their relatively high adsorptive affinities would restrict their transport within groundwater over any great distance by their adsorption to surrounding soil particulates, unless cosolvent effects mediated by more mobile, water soluble organic compounds enhance their migration in groundwater. The metals in groundwater, particularly if present as ionic species, would be expected to migrate a great distance with the groundwater flow until they are adsorbed by surrounding soil particles. Metals, and organic compounds with high adsorptive affinities, may also be transported with very fine suspended particulates and/or colloidal matter to which they are adsorbed. This scenario is verified by the non-filtered versus filtered metals groundwater data. However, any groundwater transport via suspended particulates would be anticipated to occur only for a limited distance until these fine particulates become trapped within the subsurface matrix. Any migration of contaminants in groundwater at Sites 12 and 13 will be controlled principally by groundwater flow and dilution effects, and contaminant removal mechanisms such as adsorption, equilibrium

dissolution-precipitation conditions, biodegradation, and for some constituents, limited volatilization from groundwater into interstitial voids within the overlying vadose zone soils.

#### Migration of Contaminated Surface Water and Sediment

Surface water transport at Site 12 can occur in two ways: via transport of contaminated material in the sediment load and through transport of dissolved components. The two mechanisms have sharply contrasting effects on contaminant dispersion and distribution.

Sediment transport at Site 12 is controlled by physical processes and is dependent on the rate of flow which determines the sediment load capacity of the water body. In stagnant bodies of water such as lakes, ponds or wetlands, contaminated sediments will accumulate without further significant short-term transport. In rivers and streams, some environments are points of deposition where sediments may accumulate and reside for variable periods of time. Increased flow rates increase the capacity of water bodies to transport the contaminated sediment away from the source. The pathways of contaminants bound to sediments into biota are limited to ingestion of and physical contact with the sediment.

Transport of dissolved load is a chemical process that is generally controlled by the rate of release of the contaminant from the source, which may in turn be determined by the solubility of the contaminant or by the rate of influx of a media such as contaminated ground water into the surface water body. In either case, the amount of contaminant transported is a function of the equilibrium dissolution-precipitation conditions of the specific contaminant-water system. The equilibrium rate constants dictate that higher flow levels will generally serve to dilute the contaminant, and not increase the rate of transport. Dissolved contaminant pathways into biota are ingestion of and physical contact with the water. Principal chemical contaminant classes that may migrate via surface water and sediment pathway mechanisms are discussed in the subsections that follow.

##### a) Volatile Organic Compounds

VOCs that are dissolved in unconfined surface water are not expected to persist because of rapid volatilization. VOCs do not bind to soil or sediment particles to any significant degree and transport of volatiles via sedimentary processes is not likely to be an important process. Detection of VOCs in Site 12 surface water and sediments indicate that there is a continuing source of these contaminants such as from the site groundwater or on site soils.

##### b) Semivolatile Organic Compounds

The SVOCs, in general, have low aqueous solubility. Transport of dissolved SVOCs therefore is an unlikely fate mechanism. This conclusion is supported by the surface water data from the drainage ditch in which, no SVOC's were retained as COCs.

Transport of BNAs in the sediment load of rivers and streams is, however, likely to be a significant fate process because of the high adsorptive affinity of many of the BNA compounds to organic and mineral

matter. Sediment data collected at Site 12, however, do not show the presence of SVOC's, thereby making this an insignificant transport pathway at this site.

c)      **Metals**

Transport of dissolved metals in surface water is controlled by the solubility of the individual metals, which is in turn controlled by the chemistry of the water body. Transport of contaminated sediment can occur by the physical action of water on the bed load of streams and by deposition and resuspension of suspended particles. The surface water and sediment data in site 12 indicate that transport of many inorganics may occur at levels exceeding USEPA Region III RBC levels.

Migration of Contaminants into Biota (Fish)

Contaminants may migrate into fish directly, via ingestion of either contaminated water or contaminated sediment, or indirectly through ingestion of contaminated biota belonging to a lower trophic level. Some organic compounds (e.g., VOCs) and metals (e.g. mercury) may be concentrated in fish tissue, as reflected by their bioconcentration factors.

Migration of Contaminants into Air

Contaminants may migrate into air via two distinct emission mechanisms: entrainment of contaminated particulates by the wind (i.e., fugitive dust emissions), and volatilization, primarily of organic compounds. The extent of particulate entrainment at a site is governed in large part by climate conditions (dry, windy conditions are more conducive to entrainment than wet, calm conditions). Other factors that affect entrainment of particulates include the activities that occur on the site, the extent of paved areas, and the grain size distribution of the surface soil. Volatile organic compounds can migrate into air from surface and subsurface soils. Volatilization from surface materials is essentially unrestricted and so is governed only by the physicochemical characteristics of a given compound under ambient conditions. Volatilization from subsurface materials is more complex and factors such as soil moisture and permeability must be taken into account. Migrating contaminants into air at either Sites 12 or 13 through entrainment of contaminated particles expected to be minimal or nonexistent due to the areas being either extensively paved or covered with significant vegetation. Volatilization of contaminants into the air is also expected to be minimal because of the paved areas and the fact that the VOC contamination is deep below the surface.

**6.4.3 Conceptual Site Model**

Development of a potential exposure pathway is critical in evaluating all potential exposures for human receptors. These pathways describe the area of concern in terms of suspected sources of contamination, the affected media, and all potential routes of migration of the contaminants present, in addition to impacted populations. Tables 6-6 through 6-8 detail the potential exposure pathways evaluated at each site, respectively, for both current and future populations.



TABLE 6-6

**RELATIVE MOBILITIES OF INORGANICS  
NAB LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

	Environmental Conditions			
Relative Mobility	Oxidizing	Acidic	Neutral/ Alkaline	Reducing
Very High			Se	
High	Se, Zn	Se, Zn, Cu, Ni, Hg, Ag, V	V	
Medium	Cu, Ni, Ab Hg, As, Cd	As, Cd	As, Cd	
Low	Pb, Ba, Be	Pb, Ba, Be, Sb	Pb, Ba, Be, Sb	Sb
Very Low	Fe, Cr, Mn	Cr	Cr, Zn, Cu, Ni, Hg, Ag, Al	Cr, Se, Zn, Cu, Ni, Hg, Pb, Ba, Be, Al, Ag, V

Al =	Aluminum	Fe =	Iron
Ag =	Silver	Hg =	Mercury
As =	Arsenic	Mn =	Manganese
Ba =	Barium	Ni =	Nickel
Be =	Beryllium	Pb =	Lead
Cd =	Cadmium	Se =	Selenium
Cr =	Chromium	V =	Vanadium
Cu =	Copper	Zn =	Zinc
Sb =	Antimony		

Source: Swartzbaugh (1992)

**TABLE 6-7**

**MATRIX OF POTENTIAL EXPOSURE - CURRENT AND FUTURE LAND USE  
SITE 12  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

Exposure Medium	CURRENT LAND USE SCENARIO:			FUTURE LAND USE SCENARIO:
	Trespasser Population	Worker Population	Recreational Population	Resident Population
Groundwater:				
Ingestion	-----	-----	-----	Yes*
Dermal Contact	-----	-----	-----	Yes*
Inhalation	-----	-----	-----	Yes*
Surface Water:				
Ingestion	Yes	Yes	-----	Yes
Dermal Contact	Yes	Yes	-----	Yes
Sediments:				
Ingestion	Yes	Yes	-----	Yes
Dermal Contact	Yes	Yes	-----	Yes
Fish:				
Ingestion	-----	-----	-----	Yes
Subsurface Soil				
Ingestion	-----	-----	-----	Yes
Dermal Contact	-----	-----	-----	Yes

\* Exposure frequency is reduced to recreational/trespasser population (children = 14 days/year; adult = 28 days/year).

**TABLE 6-8**

**MATRIX OF POTENTIAL EXPOSURE - CURRENT AND FUTURE LAND USE  
SITE 13  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

Exposure Medium	CURRENT LAND USE SCENARIO:			FUTURE LAND USE SCENARIO:
	Trespasser Population	Worker Population	Recreational Population	Resident Population
Surface Soil:				
Ingestion	Yes	Yes	-----	Yes
Dermal Contact	Yes	Yes	-----	Yes
Groundwater:				
Ingestion	-----	-----	-----	Yes*
Dermal Contact	-----	-----	-----	Yes*
Inhalation	-----	-----	-----	Yes*
Subsurface Soil				
Ingestion	-----	-----	-----	Yes
Dermal Contact	-----	-----	-----	Yes

\* Exposure frequency is reduced to recreational/trespasser population (children = 14 days/year; adult = 28 days/year).

**Table 6-9** summarizes the potential exposure routes, media, and exposure points identified for trespasser, residential, recreational and worker land-use scenarios at each site. In addition, the reason(s) for selection or exclusion of each pathway in the RA is presented.

The following discussion details the exposure pathway summary for both the current and future scenarios.

Surface soils at Site 13 could pose health risks to trespassers, residents, and workers via incidental ingestion and dermal contact while on-site.

Subsurface soils were evaluated in the current scenario for possible transport and mobility to the groundwater. Inorganic compounds detected in the subsurface soils are compared to the average concentrations from different literature of elements typical of soils (Bowen, H.J.M., 1979, Ure, et. al., 1983, Parr, et. al., 1983 and Shaklette, et. al., 1971). The inorganic compound that is detected at greater than the average concentration of elements typical of soils is then identified in **Table 6-5** to determine its mobility. Non-metals detected in subsurface soils were evaluated based on each individual compounds MI, as described in Section 6.1.3.4. Inorganic compounds in Site 13 are slightly immobile or immobile, and were not assumed to migrate into the site's groundwater. Subsurface soils were further evaluated in the future scenario, where the soils are brought into the surface and made available for contact. Evaluation of this pathway is similar to the surface soil exposure pathway.

Ingestion and dermal contact are included in the evaluation of the groundwater exposure pathway for the future scenario where future residential development may occur. However, the base does not plan to install any drinking water wells in the future and the likelihood of future residential development (post base-closure scenario) of drinking water wells is extremely unlikely for two primary reasons. Local city supplied drinking water is the primary drinking water source for the area. Also, due to the base's proximity to the Chesapeake Bay, the unconfined aquifer (Columbia Aquifer) is generally unsuitable for drinking water purposes. Therefore, the exposure frequency used to evaluate the future groundwater exposure scenario was based on a recreational/trespasser population. The exposure frequency is 14 days per year for children, and 28 days per year for adults. Since no drinking water wells are present at NAB Little Creek, the current scenario was not evaluated since the exposure pathway does not exist.

Exposure routes to surface waters include both dermal and ingestion pathways. It is assumed for conservatism in the dermal contact pathway that for each scenario the person accidentally falls into the drainage way. The current scenario evaluates a trespasser's and worker's exposure to site surface waters via both pathways. Both pathways were also evaluated for a resident's exposure in the future scenario. Exposures to impacted surface waters by recreational users result from use of the waterways either on-site or immediately downstream of the individual site.

Sediment exposure pathways mimic those of the surface water exposure pathways. However, the sediment concentrations were evaluated by comparing them to residential soils concentration from USEPA Region III Risk-Based Concentration Table.

Fish ingestion exposure pathways were included for Site 12 due to the potential presence of aquatic life in the waterways at the site or in these waterways in surrounding areas. Ingestion of these fish were

**TABLE 6-9**  
**EXPOSURE PATHWAY SUMMARY**  
**NAB LITTLE CREEK**  
**VIRGINIA BEACH, VIRGINIA**

Potentially Exposed Population	Exposure Route, Medium and Exposure Point	Pathway Retained for Evaluation?	Reason for Selection or Exclusion
<b>Conservative Current Land Use:</b> Trespassers: Adults and Children	Ingestion of soils, dermal contact with soil by trespassers and vagrants while temporarily residing on-site or trespassing	Yes	Possibility of usage by on-site vagrants/trespassers
	Inhalation of Soils	No	Sites are approximately 75% paved with the remaining having vegetative cover inhibiting emission of fugitive dust. Ingestion and dermal contact more conservative.
	Ingestion of groundwater, dermal contact with groundwater, inhalation of groundwater while trespassing	No	On-site use of groundwater unlikely
	Ingestion of surface water, dermal contact with surface water while on site	Yes	Exposure likely during fishing and other activities conducted by trespassers
	Ingestion of and dermal contact with sediments while on site	Yes	Potential exposures to sediments possible concurrent with surface water exposure
	Ingestion of fish from waterways adjacent to Site 12	Yes	Consumption of fish impacted by site possible
<b>Workers: Adults</b>	Ingestion of soils, dermal contact with soil while working on-site	Yes	Exposure to worker could be possible while on site
	Inhalation of Soils while working	No	Sites are approximately 75% paved with the remaining having vegetative cover that was inhibit emission of fugitive dust.
	Ingestion of groundwater, dermal contact with and inhalation of groundwater while working on site	No	On-site use of groundwater unlikely
	Ingestion of surface water, dermal contact with surface water while on site	No	On-site use of waters unlikely
	Ingestion of sediments while working on site	No	On-site use of sediments unlikely
	Ingestion of fish from waterways adjacent to site caught while working on-site	No	On-site use of fish caught from waterways impacted by site unlikely

**TABLE 6-9 (Cont'd)**  
**EXPOSURE PATHWAY SUMMARY**  
**NAB LITTLE CREEK**  
**VIRGINIA BEACH, VIRGINIA**

Potentially Exposed Population	Exposure Route, Medium and Exposure Point	Pathway Retained for Evaluation?	Reason for Selection or Exclusion
<b>Future Land Use:</b> Residents: Adults and Children	Ingestion of soils, dermal contact with soil while residing on-site	Yes	Possibility of usage by on-site future residential neighborhood
	Inhalation of soils while on site	No	Ingestion and dermal contact more conservative risk estimate
	Ingestion of, dermal contact with and inhalation of groundwater by future site residents	Yes	On-site ingestion of, dermal contact with and ingestion of groundwater via well possible
	Ingestion of surface water, dermal contact with surface water while on site	Yes	Exposure likely during fishing and other activities conducted by future residents
	Ingestion of and dermal contact with sediments while on site	Yes	Potential exposures to sediments possible concurrent with surface water exposure
	Ingestion of fish from waterways adjacent to site	Yes	Ingestion of fish impacted by site possible
Construction Worker	Ingestion of soils, dermal contact with soils	No	Residential exposure more conservative estimate of risk

evaluated for the trespasser, recreational, and worker populations in the current scenario and for the resident pathway in the future scenario. Data used in this evaluation was the maximum concentration detected in the surface water samples.

## 6.5 Quantification of Exposure

Chemical concentrations used in the estimation of chronic daily intakes (CDIs) for each medium represent each type of exposure. Exposures occur discretely or at a number of sampling locations dependent on the scenarios considered for each receptor class. Certain environmental media (i.e. groundwater, surface water and sediment) move throughout an area. Therefore, chemical concentrations detected in these media change frequently over time. Soils, by nature, are less transitory than the above-described media.

Estimates of exposure point concentrations are needed as part of the quantitative risk evaluations since these estimates are used along with the exposure scenarios to estimate chronic daily intake and subsequent human health risks.

Estimation of exposure point concentrations for ingestion and inhalation pathways are based on measured concentrations of the indicator compounds. The representative exposure point concentration was taken as the 95% UCL of the arithmetic mean of the log transformed data (or the maximum measured concentration if the 95% UCL exceeds the maximum) of the compound for the matrix in question for the reasonable maximum case. The 95% UCL was calculated using current USEPA criteria (USEPA, 1992) from the average, variance, and standard error of the natural log transformed data using the following equation:

$$95\% UCL = EXP[\bar{x} + 0.5S^2 + HS_e] \quad \text{EQUATION 6.2}$$

where  $\bar{x}$  is the mean of the natural log transformed data,  $S^2$  is the variance on the transformed data,  $S_e$  is the standard error on the transformed data, and  $H$  is the t-value for the transformed data. (The latter value differs from the tabulated t-values because of the natural log transformation of the data.) This calculation includes all analyses for a given compound in a given matrix with the non-detect results included at one-half the Detection Limit (USEPA, 1989).

Reported concentrations that were less than the method detection limit were used as positive values. Typically, these values are qualified with a "J," meaning the value is estimated. Some inorganic concentrations were reported with a "B" qualifier, meaning the compound is detected in the laboratory blank samples (see Appendix N). These concentrations were included in the data set for evaluation because they were five times the concentration measured in the blank.

This risk assessment assumes a log normal distribution of the analytical data which is consistent with USEPA's (OSWER 9285.7-081) view that in most cases, it is reasonable to assure that superfund sampling data are log normally distributed. Dean (1981) also confirms that most environmental data sets

are skewed and the data can be assumed to be log normally distributed. In addition use of the assumption that the data are log normally distributed is more conservative because calculating the UCL of the arithmetic mean based on a normal distribution may result in a lower UCL for the same data base (OSWER 9285.7-081), thereby under estimating potential risk. In addition where the site characterization may not have sampled the heavily contaminated portion of the site adequately, in such cases a UCL from a normal distribution could fall below the true mean even if a limited data set appears normally distributed, thereby under estimating the site risk.

## 6.6 Estimation of Daily Chronic Intake

The equations for estimating exposure to site contaminants for the various identified exposure pathways are as follows:

### 6.6.1 Soil

#### 6.6.1.1 Ingestion

Exposure dose calculations from incidental ingestion of soil used the following equation:

$$CDI = \frac{CS \cdot IR \cdot FI \cdot EF \cdot ED \cdot CF}{BW \cdot AT} \quad \text{Equation 6.3}$$

where:

CDI = Chronic Daily Intake, mg/kg/day  
 CS = Chemical Concentration In Soil, mg/kg  
 IR = Ingestion Rate, mg/day  
 FI = Fraction Ingested From Source, unitless  
 EF = Exposure Frequency, day/year  
 ED = Exposure Duration, year  
 CF = Conversion Factor, kg/mg  
 BW = Body Weight, kg  
 AT = Averaging Time, day

#### 6.6.1.2 Dermal

Exposure dose from dermal contact with soil was calculated using the following equation (USEPA, 1989):

$$CDI = \frac{CS \cdot SA \cdot AF \cdot ABS \cdot EF \cdot ED \cdot CF}{BW \cdot AT} \quad \text{Equation 6.4}$$

where:

CDI = Chronic Daily Intake, mg/kg/day  
 CS = Chemical Concentration In Soil, mg/kg



SA =	Surface Area Of Exposed Skin, cm <sup>2</sup> /event
AF =	Soil Adherence To Skin, mg/cm <sup>2</sup>
ABS =	Percent of Constituent Absorbed, unitless
EF =	Exposure Frequency, day/year
ED =	Exposure Duration, year
CF =	Conversion Factor, kg/mg
BW =	Body Weight, Kg
AT =	Averaging Time, day

## 6.6.2 Groundwater

### 6.6.2.1 Ingestion

Exposure dose from ingestion of groundwater was calculated using the following equation:

$$CDI = \frac{CS \cdot CR \cdot FI \cdot EF \cdot ED \cdot CF}{BW \cdot AT} \quad \text{Equation 6.5}$$

where:

CDI =	Chronic Daily Intake, mg/kg/day
CS =	Chemical Concentration In Water, µg/L
CR =	Ingestion Rate, L/day
FI =	Fraction Ingested From Source, unitless
EF =	Frequency of Exposure, days/year
ED =	Exposure Duration, years
CF =	Conversion Factor, mg/µg
BW =	Body Weight, kg
AT =	Averaging Time, days

### 6.6.2.2 Dermal Contact

The exposure dose from dermal contact with groundwater was calculated using the following equation (USEPA, 1989):

$$CDI = \frac{CW \cdot SA \cdot PC \cdot ET \cdot EF \cdot ED \cdot CF}{BW \cdot AT} \quad \text{Equation 6.6}$$

where:

CDI =	Chronic Daily Intake, mg/kg/day
CW =	Chemical Concentration In Water, µg/L
SA =	Surface Area Of Exposed Skin, cm <sup>2</sup> /event
PC =	Chemical Specific Dermal Permeability Constant, cm/hour
ET =	Exposure Time, hours/day
EF =	Frequency of Exposure, days/year

ED =	Exposure Duration, years
CF =	Volumetric Conversion Factor, $\text{mg} \cdot \text{l}/\text{cm}^3 \cdot \mu\text{g}$
BW =	Body Weight, kg
AT =	Averaging Time, days

#### 6.6.2.3 Inhalation

The risk from inhalation of volatile organic contaminants from groundwater was evaluated through a shower model. Groundwater volatile contaminant inhalation exposure occurs in the home during such activities as washing, bathing, laundering, cooking and showering. Foster and Chrostowski (1987) have shown in their model that inhalation of volatile organic contaminants from water during typical home usage can be a significant exposure route. Since groundwater at NAB Little Creek Sites 12 and 13 has been found to contain potentially carcinogenic volatile organic contaminants, and the potential exists for the groundwater on-site to become a source of potable water in the future, these matrices were evaluated for carcinogenic risk and noncarcinogenic health effects through use of a shower model and exposure scenario. The exposure while showering is conservatively evaluated, and likely does not significantly underestimate total home use exposures.

Equation (Foster and Chrostowski, 1987):

$$E_{\text{inh}} = (\text{VR})(\text{S}) / [(\text{BW})(\text{R})(10^{-6})] \times [\text{Ds} + \exp(-\text{RDt})/\text{R} - \exp(\text{Ds}-\text{Dt})/\text{R}]$$

Parameters:

$E_{\text{inh}}$	=	Inhalation exposure per shower (mg/kg/shower)
BW	=	Body weight (Kg)
R	=	Air exchange rate ( $\text{min}^{-1}$ )
Ds	=	Shower Duration (min)
Dt	=	Total Duration in shower room (min)
VR	=	Ventilation Rate (1/min)
S	=	Indoor VOC generation rate ( $\text{ug}/\text{m}^3/\text{min}$ ) Determined by $S = \text{Cwd} (\text{FR})/\text{SV}$

Where:	Cwd	=	Concentration leaving shower droplet after time Ts ( $\text{ug}/\text{l}$ )
	FR	=	Shower Flow Rate (1/min)
	SV	=	Shower Room air volume ( $\text{m}^3$ )

Cwd is calculated by the following equation:

$$\text{Cwd} = \text{Cwo} (1 - \exp [-(\text{Kal})(\text{ts})/60\text{d}])$$

Where:	Cwo	=	shower water concentration ( $\text{ug}/\text{l}$ )
	d	=	shower droplet diameter (mm)

ts = shower drop time (sec)  
 Kal = adjusted overall mass transfer coefficient (cm/hr)

Kal is determined by the following equation:

$$K_{al} = K_L (T_i U_s / T_s U_i)^{-0.5}$$

Where: Ti = calibration water temperature of  $K_L$  in °K  
 Ts = shower water temperature (°K)  
 Ui = water viscosity at Ti (cp)  
 Us = water viscosity at Ts (cp)  
 $K_L$  = overall mass transfer coefficient (cm/hr)

$$K_L = (1/k_i + RT/Hk_g)^{-1}$$

Where: H = Henry's Law Constant (atm-m<sup>3</sup>)/mol-K  
 RT = 2.4x10<sup>-2</sup> atm-m<sup>3</sup>/mole  
 kg = gas-film transfer coefficient (cm/hr)  
 ki = liquid film mass transfer coefficient (cm/hr)

Typical values of ki = 20 cm/hr, and kg = 3,000 cm/hr

### 6.6.3 Surface Water

#### 6.6.3.1 Ingestion

Exposure dose calculation from incidental ingestion of surface water used the following equation (USEPA, 1989):

$$CDI = \frac{CS \cdot CR \cdot FI \cdot EF \cdot ED \cdot CF}{BW \cdot AT} \quad \text{Equation 6.8}$$

where:

CDI = Chronic Daily Intake, mg/kg/day  
 CS = Chemical Concentration In Water, µg/L  
 CR = Ingestion Rate, L/day  
 FI = Fraction Ingested From Source, unitless  
 EF = Frequency of Exposure, days/year  
 ED = Exposure Duration, years  
 CF = Conversion Factor, mg/µg  
 BW = Body Weight, kg  
 AT = Averaging Time, days

#### 6.6.3.2 Dermal Contact

The exposure dose from dermal contact with surface water was calculated using the following equation (USEPA, 1989):

$$CDI = \frac{CS \cdot SA \cdot PC \cdot ET \cdot EF \cdot ED \cdot CF}{BW \cdot AT} \quad \text{Equation 6.9}$$

where:

CDI =	Chronic Daily Intake, mg/kg/day
CS =	Chemical Concentration In Water, $\mu\text{g/L}$
SA =	Surface Area Of Exposed Skin, $\text{cm}^2/\text{event}$
PC =	Chemical Specific Dermal Permeability Constant, $\text{cm}/\text{hour}$
ET =	Exposure Time, $\text{hours}/\text{day}$
EF =	Frequency of Exposure, $\text{days}/\text{year}$
ED =	Exposure Duration, $\text{years}$
CF =	Volumetric Conversion Factor, $1 \cdot \text{mg}/\text{cm}^3 \cdot \mu\text{g}$
BW =	Body Weight, $\text{kg}$
AT =	Averaging Time, $\text{days}$

#### 6.6.4 Sediment

##### 6.6.4.1 Ingestion

The exposure dose from the ingestion of contaminated sediment was calculated using the following equation (USEPA, 1989):

$$CDI = \frac{CS \cdot IR \cdot FI \cdot EF \cdot ED \cdot CF}{BW \cdot AT} \quad \text{Equation 6.10}$$

where:

CDI =	Chronic Daily Intake, $\text{mg}/\text{kg}/\text{day}$
CS =	Concentration of Contaminant In Sediment, $\text{mg}/\text{kg}$
IR =	Rate of Sediment Ingestion, $\text{mg}/\text{day}$
FI =	Fraction of Sediment Ingested, unitless
EF =	Frequency of Exposure, $\text{days}/\text{year}$
ED =	Exposure Duration, $\text{years}$
CF =	Conversion Factor, $\text{kg}/\text{mg}$
BW =	Body Weight, $\text{kg}$
AT =	Averaging Time, $\text{days}$

#### 6.6.4.2 Dermal Contact

The exposure dose from dermal contact with contaminated sediment was calculated using the following equation (USEPA, 1989):

$$CDI = \frac{CS \cdot SA \cdot AF \cdot ABS \cdot ET \cdot EF \cdot ED \cdot CF}{BW \cdot AT} \quad \text{Equation 6.11}$$

where:

CDI =	Chronic Daily Intake, mg/kg/day
CS =	Concentration of Contaminant In Sediment, mg/kg
SA =	Surface Area Of Exposed Skin, cm <sup>2</sup> /event
AF =	Sediment Adherence To Skin, mg/cm <sup>2</sup>
ABS =	Percent of Constituent Absorbed, unitless
ET =	Exposure Time, hours/day
EF =	Frequency of Exposure, days/year
ED =	Exposure Duration, years
CF =	Conversion Factor, kg/mg
BW =	Body Weight, kg
AT =	Averaging Time, days

#### 6.6.5 Fish

##### 6.6.5.1 Ingestion

The exposure dose from the ingestion of contaminated fish resulted from the following two equations (USEPA, 1989):

$$(1) \quad FC = BCF \cdot CS \quad \text{Equation 6.12}$$

where:

FC =	Constituent Concentration in Fish, mg/kg
BCF =	Bioconcentration Factor, l/kg
CS =	Constituent Concentration in Surface Water or Sediment, mg/l

$$(2) \quad CDI = \frac{FC \cdot IR \cdot FI \cdot EF \cdot ED \cdot CF}{BW \cdot AT} \quad \text{Equation 6.13}$$

where:

CDI =	Chronic Daily Intake, mg/kg/day
FC =	Fish Concentration, mg/kg
IR =	Ingestion Rate, g/day
FI =	Fraction Ingested From Source, unitless
EF =	Exposure Frequency, day/year

ED =	Exposure Duration, day/year
CF =	Conversion Factor, kg/g
BW =	Body Weight, kg
AT =	Averaging Time, day

### Exposure Input Parameters

A summary of the exposure input parameters for the sites are provided in **Table 6-10** for the current scenario and **Table 6-11** for the future scenario. These parameters were obtained from:

- Dermal Exposure Assessment: Principles and Applications - Interim Report. USEPA, 1992.
- Risk Assessment Guidance for Superfund, Volume I - Human Health Evaluation Manual (Part A) Interim Final. USEPA, 1989.
- Exposure Factors Handbook. USEPA, 1989.
- "Selecting Exposure Routes and Contaminants of Concern by Risk-Based Screening", USEPA, 1993.
- Water Quality Criteria Summary: USEPA, 1991.
- Superfund Exposure Assessment Manual. USEPA, 1988.

Parameters used for the future exposure, groundwater pathway, were determined using professional judgment and site specific characteristics.

Determining exposure inputs for the current scenario and future scenario were based on the following uses. Current land use included site usage by trespassers, recreational population visiting the site, and base employees. The trespasser and recreational child/adult were evaluated as ingesting and in dermal contact with water and sediments from the waterways impacted by the sites. Consequently, trespassers and the recreational population consume fish caught in the surface waters of the sites. Base workers, trespassers, and the recreational population are exposed to the site's surface soil. Future residential land use incorporates the potential of future site development into a residential neighborhood. Although a groundwater exposure pathway for future residents is not expected since groundwater is not the source of the water supply in the area, a groundwater future scenario is still evaluated for conservatism (see Section 6.1.3.2). The groundwater exposure frequency used is similar to a trespasser/recreational receptor, 14 days/year for a child, and 28 days/year for an adult.

Due to the transitory nature of surface water, sediment, and fish, recreational pathways were evaluated under the current scenario. Based on either future site development into a residential neighborhood, future residential exposure provides a conservative assessment of exposure to all pathways, including groundwater.

TABLE 6-10

**CURRENT EXPOSURE  
INPUT PARAMETERS  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

Input Parameter	Exposure Pathway	Units	Receptor					References
			Trespasser		Recreational		Worker	
			Child	Adult	Child	Adult	Adult	
IR, Ingestion Rate	Soil	mg/d	200	100	67	33	50	Note 1 USEPA, 1989(a); Note 3 USEPA, 1991 USEPA, 1989(b)
	Sediment	mg/d	100	50.0	100	50.0	50	
	Food	g/d	6.5	6.5	6.5	6.5	6.5	
CR, Consumption Rate	Surface Water	l/d	2	2	2	2	2	
FI, Fraction Ingested	Soil	unitless	1	1	1	1	1	
From	Sediment	unitless	1	1	1	1	1	
Source	Food	hour/day	2.6	2.6	2.6	2.6	0.3	USEPA, 1988; Note 2
ET, Exposure Time	Surface Water	day/year	14	28	14	28	250	USEPA, 1992(a); USEPA, 1993
EF, Exposure Frequency	(dermal)	day/year	14	28	14	28	250	USEPA, 1993; Note 5
	Soil	day/year	350	350	14	28	250	USEPA, 1993
	Sediment	year	6	30	6	30	25	USEPA, 1989(a)
ED, Exposure Duration	Surface Water	kg	15	70	15	70	70	USEPA, 1993
BW, Body Weight	All pathways							USEPA, 1989(a); Note 4
AT, Averaging Time	All Media	day	2190	10950	2190	10950	9125	
ATnc, noncarcinogenic	All Media	day	25550	25550	25550	25550	25550	USEPA, 1989(a); USEPA, 1989(b); USEPA, 1989(a); USEPA, 1989(b)
ATc, carcinogenic	All Media	day	25550	25550	25550	25550	25550	USEPA, 1992(a)
SA, Skin Surface Area	Soil	cm <sup>2</sup>	1820	5800	1820	5800	5800	USEPA, 1992(a)
Available for Contact	Surface	cm <sup>2</sup>	7280	23000	7280	23000	23000	USEPA, 1992(a)
	Water	cm <sup>2</sup>	7280	23000	7280	23000	23000	USEPA, 1992(a)
	Sediment							USEPA, 1992(a)
PC, Permeability Constant	Surface Water	cm/hr	See Appendix K for Chemical-Specific					USEPA, 1992(a)
Shower Room Water for Shower		m <sup>3</sup>	12	12	12	12	12	Conservative Assumption
AF, Adherence Factor	Soil	L	200	200	200	200	200	Conservative Assumption
	Sediment	mg/cm <sup>2</sup>	1	1	1	1	1	USEPA, 1992(a)
ABS, Absorbance Factor		mg/cm <sup>2</sup>	1	1	1	1	1	USEPA, 1992(a)
Inorganics	All Media	NA	0.01	0.01	0.01	0.01	0.01	Ryan et.al. (1987)
PCBs	All Media	NA	0.06	0.06	0.06	0.06	0.06	USEPA, 1992(a)
VOAs	All Media	NA	0.25	0.25	0.25	0.25	0.25	Ryan et.al. (1987)
SVOCs	All Media	NA	0.10	0.10	0.10	0.10	0.10	Ryan et.al. (1987)
Arsenic	All Media	NA	0.03	0.03	0.03	0.03	0.03	Wester et.al. (1993)

TABLE 6-10 (Cont'd)

**CURRENT EXPOSURE  
INPUT PARAMETERS  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

Input Parameter	Exposure Pathway	Units	Receptor					References
			Trespasser		Recreational		Worker	
			Child	Adult	Child	Adult	Adult	
GI Absorbance Factor								
Chlorobenzene	All Media	NA	0.30	0.30	0.30	0.30	0.30	Ohio EPA
Arsenic	All Media	NA	0.95	0.95	0.95	0.95	0.95	USEPA Region III
Barium	All Media	NA	1.00	1.00	1.00	1.00	1.00	USEPA Region III
Beryllium	All Media	NA	0.01	0.01	0.01	0.01	0.01	USEPA Region III
Cadmium								
Water	All Media	NA	0.05	0.05	0.05	0.05	0.05	USEPA Region III
Food	All Media	NA	0.025	0.025	0.025	0.025	0.025	USEPA Region III
Copper	All Media	NA	0.60	0.60	0.60	0.60	0.60	USEPA Region III
Manganese	All Media	NA	0.05	0.05	0.05	0.05	0.05	USEPA Region III
Mercury	All Media	NA	0.15	0.15	0.15	0.15	0.15	USEPA Region III
Nickel	All Media	NA	0.043	0.043	0.043	0.043	0.043	USEPA Region III
Vanadium	All Media	NA	0.026	0.026	0.026	0.026	0.026	Ohio EPA
Zinc	All Media	NA	0.25	0.25	0.25	0.25	0.25	USEPA Region III
VOCs	All Media	NA	0.80	0.80	0.80	0.80	0.80	USEPA Region IV
SVOCs/Pest	All Media	NA	0.50	0.50	0.50	0.50	0.50	USEPA Region IV
Inorganics	All Media	NA	0.20	0.20	0.20	0.20	0.20	USEPA Region IV

**Notes:**

1. Soil ingestion rates for trespasser and worker receptors are based on Risk Assessment Guidance for Superfund Volume 1 Human Health Evaluation Manual (Part A) - USEPA, 1989(a). Recreational receptors are based on an 8 hour exposure per day, therefore, child:  $67 \text{ mg/d} = 200 \text{ mg/d} * (\text{d}/24 \text{ hr}) * 8 \text{ hr/d}$ , and adult:  $33 \text{ mg/d} = 100 \text{ mg/d} * (\text{d}/24 \text{ hr}) * 8 \text{ hr/d}$ .
2. Dermal exposure rates via surface water for trespasser and recreational receptors are based on Superfund Exposure Assessment Manual - USEPA, 1988. The worker dermal exposure via surface water is based on a 20 minute per day exposure resulting to a  $0.3 \text{ hr/d} = 20 \text{ min/d} * (\text{hr}/60 \text{ min.})$ .
3. Sediment ingestion rates for trespasser child receptor is based on  $100 \text{ mg/d}$  (age groups greater than 6 years old) (USEPA, 1989(a)). The adult and worker sediment ingestion rates are based on one-half of the child rates (conservative assumption).
4. Body weight for children (up to 6 years of age) used conservatively 15 kg as default (USEPA, 1990(a), and as suggested by DEQ.
5. The adult exposure frequency of 28 days per year was determined by assuming exposure occurred one day per week recreational crabbing during the season from May to November (conservative assumption). The child's frequency was assumed to be one-half of the adults, assumed that a child (up to 6 years old) would not be crabbing without an adult (conservative assumption).



TABLE 6-11

FUTURE EXPOSURE  
INPUT PARAMETERS  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA

Input Parameter	Exposure Pathway	Units	Receptor		References
			Resident		
			Child	Adult	
IR, Ingestion Rate	Soil	mg/d	200	100	WSEPA, 1989(a) Note 1 USEPA, 1991 USEPA, 1993 USEPA, 1989(a)
	Sediment	mg/d	100	50.0	
	Food	g/d	6.5	6.5	
CR, Consumption Rate	Groundwater	l/d	1	2	USEPA, 1993 USEPA, 1989(a)
	Surface Water	l/d	2	2	
FI, Fraction Ingested From Source	Soil	unitless	1	1	USEPA, 1988
	Sediment	unitless	1	1	
	Groundwater	unitless	1	1	
ET, Exposure Time	Surface Water (dermal)	hour/day	2.6	2.6	USEPA, 1988; Note 2
	Groundwater (dermal)	min/day	12	12	
EF, Exposure Frequency	Surface Water	day/year	350	350	USEPA, 1992(a); USEPA, 1993 USEPA, 1992(a);Note 5 USEPA, 1993 USEPA, 1992(a);Note 3 USEPA, 1989(a) USEPA, 1993 USEPA, 1989(a);Note 4
	Soil		350	350	
	Sediment		14	28	
	Food		350	350	
	Groundwater		14	28	
ED, Exposure Duration	All pathways	year	6	30	USEPA, 1989(a) USEPA, 1993 USEPA, 1989(a);Note 4
BW, Body Weight	All Media	kg	15	70	
AT, Averaging Time					
ATnc, noncarcinogenic	All Media	day	2190	10950	USEPA, 1989(a) USEPA, 1989(b) USEPA, 1989(a); USEPA, 1989(b) USEPA, 1992(a) USEPA, 1992(a) USEPA, 1992(a) USEPA, 1992(a)
ATc, carcinogenic	All Media	day	25550	25550	
SA	Soil	cm^2	1820	5800	USEPA, 1992(a) USEPA, 1992(a) USEPA, 1992(a) USEPA, 1992(a)
	Surface Water	cm^2	7280	23000	
	Sediment	cm^2	7280	23000	
	Groundwater	cm^2	7280	23000	
PC, Permeability Constant	Surface Water	cm/hr	See Appendix K for Chemical-Specific		USEPA, 1992(a) USEPA, 1992(a)
	Groundwater	cm/hr	See Appendix K for Chemical-Specific		
Shower Room		m^3	12	12	Conservative Assumption Conservative Assumption
Water for Shower		L	200	200	
AF, Adherence Factor	Soil	mg/cm^2	1	1	USEPA, 1992(a) USEPA, 1992(a)
	Sediment	mg/cm^2	1	1	
ABS, Absorbance Factor	All Media	NA	0.01	0.01	Ryan et.al. (1987) USEPA, 1992(a) Ryan et.al. (1987) Ryan et.al. (1987) Wester (1993)
	Inorganics	NA	0.06	0.06	
	PCBs	NA	0.25	0.25	
	VOAs	NA	0.10	0.10	
	SVOCs	NA	0.10	0.10	
	Arsenic	NA	0.03	0.03	

TABLE 6-11

**FUTURE EXPOSURE  
INPUT PARAMETERS  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

Input Parameter	Exposure Pathway	Units	Receptor		References
			Resident		
			Child	Adult	
GI Absorbance Factor					
Chlorobenzene	All Media	NA	0.30	0.30	Ohio EPA
Arsenic	All Media	NA	0.95	0.95	USEPA Region III
Barium	All Media	NA	1.00	1.00	USEPA Region III
Beryllium	All Media	NA	0.01	0.01	USEPA Region III
Cadmium					
Water	All Media	NA	0.05	0.05	USEPA Region III
Food	All Media	NA	0.025	0.025	USEPA Region III
Copper	All Media	NA	0.60	0.60	USEPA Region III
Manganese	All Media	NA	0.05	0.05	USEPA Region III
Mercury	All Media	NA	0.15	0.15	USEPA Region III
Nickel	All Media	NA	0.043	0.043	USEPA Region III
Vanadium	All Media	NA	0.026	0.026	Ohio EPA
Zinc	All Media	NA	0.25	0.25	USEPA Region III
VOCs	All Media	NA	0.80	0.80	USEPA Region IV
SVOCS/Pest	All Media	NA	0.50	0.50	USEPA Region IV
Inorganics	All Media	NA	0.20	0.20	USEPA Region IV

## Notes:

1. Sediment ingestion rates for trespasser child receptor is based on 100 mg/d (age groups greater than 6 years old) (USEPA, 1989(a)). The adult and worker sediment ingestion rates are based on one-half of the child rates (conservative assumption).
2. Groundwater exposure time (ET) is via showering/bathing where a possibility of using groundwater as water supply source exists.
3. Receptors are exposed only as a trespasser/recreational.
4. Body weight for children (up to 6 years of age) used conservatively 15 kg as default (USEPA, 1990(a)), and as suggested by DEQ.
5. The adult exposure frequency of 28 days per year was determined by assuming exposure occurred one day per week recreational crabbing during the season from May to November (conservative assumption). The child's frequency was assumed to be one-half of the adults, assumed that a child (up to 6 years old) would not be crabbing without an adult (conservative assumption).

Worker population exposures were based on-site maintenance personnel and base personnel which may come into contact with soil media in the current scenario while completing their duties. As previously stated, the future scenario was assessed for residential exposure only, which provides a conservative maximum risk which may occur at the sites.

## **6.7     Toxicity Assessment**

This section provides brief reviews of the available toxicological information for COCs retained for quantitative evaluation. Appendix J contains toxicological profiles for COCs identified at the sites for compounds contributing significantly to each site's total risks, both carcinogens and toxics.

### **6.7.1   Toxicological Evaluation**

This section identifies potential health and environmental effects associated with potential exposure to the final COCs chosen. A toxicological evaluation characterizes the inherent toxicity of a compound. It consists of a review of scientific data to determine the nature and extent of the potential human health and environmental effects associated with potential exposure to the various chemicals. The end product is a collection of toxicological profiles for the COCs. These toxicological profiles provide the qualitative weight-of-evidence that demonstrates whether potential COCs pose any actual or potential health and environmental effects.

These toxicological profiles incorporate data from the sources where carcinogenicity and toxicological factors were obtained. Sufficient human data are often unavailable for determining quantitative indices of toxicity because of uncertainties in exposure estimates, and inherent difficulties in determining causal relationships established by epidemiological studies. For this reason, animal bioassays are conducted under controlled conditions and their results are extrapolated to humans. Several stages occur during this extrapolation. First, to account for species differences, conversion factors are utilized when extrapolating data from test animals to humans. Second, the relatively high doses administered to test animals are extrapolated to the lower doses more typical of human exposures. For potential noncarcinogens, safety factors and modifying factors are then applied to animal results when developing acceptable human doses. For potential carcinogens, mathematical models are used to extrapolate effects at high doses to effects at lower doses. Epidemiological data can then be used for inferential purposes to establish the credibility of the experimentally derived indices.

Toxic effects considered include noncarcinogenic (toxic) and potentially carcinogenic health effects, as well as environmental effects. Toxicological endpoints, routes of exposure, and doses in humans and/or animal studies are presented. Potential carcinogenic health effects are associated with exposure to a potential carcinogen. Routes of exposure and doses in humans and/or animal studies are provided, if available. USEPA's weight-of-evidence of a compound's carcinogenicity (i.e., Group A, known human carcinogens; Group B, probable human carcinogens; Group C, possible human carcinogens; Group D, not classifiable as to its carcinogenicity), are also considered. **Table 6-12** presents this information for the COCs identified at the subject sites. Environmental effects include acute and chronic toxic effects observed in aquatic biota and terrestrial wildlife.

TABLE 6-12

**TOXICITY AND CARCINOGENITY FACTORS  
FOR CHEMICALS OF CONCERN  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

Constituent	RfD mg/kg/d	Source	RfI mg/kg/d	Source	CSF (mg/kg/d)-1	Source	CSFI (mg/kg/d)-1	Source	WOE*
<b>VOLATILES</b>									
Vinyl Chloride					1.90E+00	b	3.00E-01	b	A
1,2-Dichloroethene (total)	9.00E-03	a							B
1,1-Dichloroethene	9.00E-03	a			6.00E-01	a	1.75E-01	a	C
1,4-Dichlorobenzene			2.29E-01	a	2.40E-02	b			C
1,1,2,2-Tetrachloroethane					2.00E-01	a	2.03E-01	a	
Trichloroethene	6.00E-03	d			1.10E-02	f	6.00E-03	d	B2
Tetrachloroethene	1.00E-02	a			5.20E-02	d	2.03E-03	a	B2
Benzene			1.71E-03	d	2.90E-02	a	2.90E-02	a	A
Chlorobenzene	2.00E-02	a	5.71E-03	b					D
Chloroform	1.00E-02	a			6.10E-03	a	8.05E-02	a	B2
Xylenes (total)	2.00E+00	a							D
Toluene	2.00E-01		1.14E-01						D
<b>SEMI-VOLATILES</b>									
2-Methylnaphthalene	4.00E-02	g							D
4-Methylphenol	5.00E-03	b							C
2,4-Dimethylphenol	2.00E-02	a							D
Naphthalene	4.00E-02	a							D
Acenaphthene	6.00E-02	a							D
Fluorene	4.00E-02	a							D
Pentachlorophenol	3.00E-02	a			1.20E-01	a			B2
Phenanthrene	2.90E-02	c							D
Phenol	6.00E-01								
Anthracene	3.00E-01	a							D
Carbazole					2.00E-02	b			B2
Fluoranthene	4.00E-02	a							D
Pyrene	3.00E-02	a							D
Butylbenzyl-phthalate	2.00E-01	a							C
Benzo(a)anthracene					7.30E-01	f	6.10E-01		B2
Benzo(b)fluoranthene					7.30E-01	f	6.10E-01		B2
Benzo(k)fluoranthene					7.30E-02	f	6.10E-02		B2
Benzo(a)pyrene					7.30E+00	a	6.10E+00		B2
Indeno(1,2,3-cd)pyrene					7.30E-01	f	6.10E-01		B2
Benzo(g,h,i)pyrene					1.55E-01	h			D
Chrysene					7.30E-03	f	6.10E-03		B2
Dibenzo(a,h)anthracene					7.30E+00	f	6.10E+00		B2

RfD - Reference Dose  
CSF - Cancer Slope Factor  
WOE - Weight of Evidence

RfDI - Inhalation Reference Dose  
CSFI - Inhalation Cancer Slope Factor

\* EPA Weight of Evidence Classification System for Carcinogenicity

A	Human carcinogen
B1 or B2	Probable human carcinogen
	B1 indicates that limited human data are available.
	B2 indicates sufficient evidence in animals or no evidence in humans.
C	Probable human carcinogen
D	Not classifiable as to human carcinogenicity
E	Evidence of noncarcinogenicity

Source:

a = IRIS; b = HEAST; c = HEAST alternate method; d = USEPA/903/R-93-001, July 11, 1994; e = withdrawn from IRIS;  
f = Used Toxicity Equivalence Factor (TEF) from "A Review of PAH Sources", Toxics Integration Branch, Office of Emergency and Remedial Response, Region IV; g = Information obtained from USEPA Environmental Criteria and Assessment Office.  
h = USEPA/903/r-93-001, October 26, 1992.

TABLE 6-12 (CONTINUED)

**TOXICITY AND CARCINOGENITY FACTORS  
FOR CHEMICALS OF CONCERN  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

Constituent	RfD mg/kg/d	Source	RfI mg/kg/d	Source	CSF (mg/kg/d)-1	Source	CSFI (mg/kg/d)-1	Source	WOE*
<b>PCBs AND PESTICIDES</b>									
Heptachlor-epoxide	1.30E-05	a			9.10E+00	a	9.10E+00	a	B2
4,4'-DDE					3.40E-01	a			B2
Endrin	3.00E-04	a							D
Dieldrin	5.00E-05	a			1.60E+01	a	1.61E+01	a	D
Dibenzofuran	4.00E-03	g							
4,4'-DDD					2.40E-01	a			B2
4,4'-DDT	5.00E-04	a			3.40E-01	a	3.40E-01	a	B2
Alpha-chlordane	6.00E-05	a			1.30E+00	a	1.29E+00	a	B2
Gamma-chlordane	6.00E-05	a			1.30E+00	a	1.29E+00	a	B2
Aldrin	3.00E-05				1.70E+01		1.71E+01	a	B2
Heptachlor	5.00E-04				4.50E+00		4.55E+00	a	B2
<b>INORGANICS</b>									
Aluminum	1.00E+00	d							D
Arsenic	3.00E-04	a			1.50E+00	a	1.51E+01		A
Antimony	4.00E-04	a							D
Barium	7.00E-02	a	1.43E-04	c					D
Beryllium	5.00E-03	a			4.30E+00	a	8.40E+00	a	B2
Cadmium	5.00E-04	a					6.30E+00	a	B1
Chromium VI	5.00E-03	a					4.20E+01	a	A
Cobalt	6.00E-02	d							
Copper	4.00E-02	b							D
Iron	3.00E-01	g							D
Manganese	1.40E-01	a	1.43E-05	a					D
Mercury	3.00E-04	a	8.57E-03	b					D
Nickel	2.00E-02	a							A
Selenium	5.00E-03	a							D
Silver	5.00E-03	a							D
Vanadium	7.00E-03	b							D
Zinc	3.00E-01	a							D

RfD - Reference Dose  
CSF - Cancer Slope Factor  
WOE - Weight of Evidence

RfDI - Inhalation Reference Dose  
CSFI - Inhalation Cancer Slope Factor

\* EPA Weight of Evidence Classification System for Carcinogenicity

A	Human carcinogen
B1 or B2	Probable human carcinogen
	B1 indicates that limited human data are available.
	B2 indicates sufficient evidence in animals or no evidence in humans.
C	Probable human carcinogen
D	Not classifiable as to human carcinogenicity
E	Evidence of noncarcinogenicity

Source:

a = IRIS; b = HEAST; c = HEAST alternate method; d = USEPA/903/R-93-001, July 11, 1994; e = withdrawn from IRIS;  
f = Used Toxicity Equivalence Factor (TEF) from "A Review of PAH Sources", Toxics Integration Branch, Office of Emergency and Remedial Response, Region IV; g = Information obtained from USEPA Environmental Criteria and Assessment Office.

Although the COCs may potentially cause adverse health and environmental impacts, dose-response relationships and the potential for exposure must be evaluated before the risk to receptors can be determined. Dose-response relationships correlate the magnitude of the dose with the probability of toxic effects, as discussed in the following section.

### 6.7.2 Dose-Response Evaluation

The relationship between the dose of a compound (amount to which an individual or population is potentially exposed) and the potential for adverse health effects resulting from exposure to that dose is incorporated in the RA. Dose-response relationships provide a means by which potential public health impacts may be evaluated. Standard reference doses and/or carcinogenic slope factors have been developed for the final COCs selected and are tabulated in **Table 6-12**. This section provides a brief description of these parameters.

**Reference Doses (RfDs)** - RfDs are developed for chronic and/or subchronic human exposure to chemicals and based solely on the noncarcinogenic effects of chemical substances. These values are an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of adverse effects during a lifetime. An RfD is usually expressed as dose (mg) per unit body weight (kg) per unit time (day). An RfD is generally developed by dividing a no-observed-adverse-effect-level (NOAEL or NOEL) or a lowest-observed-adverse-effect-level (LOAEL or LOEL) for the critical toxic effect by an appropriate "uncertainty factor (UF)." Effect levels are determined from laboratory or epidemiological studies. Uncertainty factors are based upon the availability of toxicity data.

Uncertainty factors usually consist of multiples of 10, where each factor represents a specific area of uncertainty naturally present in the extrapolation process. These uncertainty factors are presented below [Risk Assessment Guidance Document for Superfund, Volume I, Human Health Evaluation Manual (Part A) (USEPA, 1989)].

- Use a UF of 10 to account for the variation in the general population and to protect sensitive subpopulations (e.g., elderly, children).
- Use a UF of 10 when extrapolating from animals to humans. This factor is intended to account for the interspecies variability between humans and other mammals.
- Use a UF of 10 when a NOAEL derived from a subchronic instead of a chronic study is the basis for a chronic RfD.
- Use a UF of 10 when a LOAEL is used instead of a NOAEL. This factor accounts for the uncertainty associated with extrapolating from LOAELs to NOAELs.

In addition to UFs, a modifying factor (MF) is applied to each reference dose. Modifying factors are:

- An MF ranging from  $> 0$  to 10 reflects a qualitative professional assessment of additional uncertainties in the base study and in the entire data base for the chemical not explicitly addressed by the preceding uncertainty factors. The default value for the MF is 1.

Thus, an RfD incorporates the certainty of the evidence for chronic human health effects. Even if applicable human data exist, the RfD maintains a margin of safety such that chronic human health effects are not underestimated.

**Carcinogenic Slope Factor (CSF)** - Carcinogenic slope factors are used when estimating an upper-bound lifetime probability of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen (USEPA, 1989). This factor is generally reported in units of  $(\text{mg/kg/day})^{-1}$  and is derived through an assumed low-dosage linear multi-stage model and an extrapolation from high to low dose responses determined from animal studies. The value used in reporting the slope factor is the upper 95 percent confidence limit.

CSFs are also derived from USEPA promulgated unit risk values for air and/or water. CSFs derived from unit risks cannot, however, be applied to environmental media other than the medium considered in the unit risk estimate.

These slope factors are also accompanied by weight-of-evidence classifications which designate the strength of the evidence that the COC is a potential human carcinogen.

Quantitative indices of toxicity and USEPA weight-of-evidence classifications are presented in **Table 6-19** for the identified COCs. The hierarchy (USEPA, 1989) for choosing these values was:

- Integrated Risk Information System (IRIS)
- Health Effects Assessment Summary Table (HEAST)
- Region III Specific Directives

The IRIS data base is updated monthly and contains both verified RfDs and CSFs. The USEPA has formed an RfD work group to review existing data used in deriving RfDs. Once this task has been completed, the verified RfD appears in IRIS. Like the RfD Work Group, the USEPA has also formed the Carcinogen Risk Assessment Verification Endeavor (CRAVE) Work Group to review and validate toxicity values used in developing CSFs. Once slope factors have been verified via extensive peer review, they also appear in the IRIS data base.

HEAST, on the other hand, provides both interim (unverified) and verified RfDs and CSFs. This document incorporates any applicable changes to its data base.

## 6.8 Risk Characterization

This section presents and discusses the estimated incremental lifetime cancer risks (ICR) and hazard indices (HI) for identified potential receptor groups which could be exposed to COCs by the exposure pathways previously identified for each site.

Quantitative risk calculations for potentially carcinogenic compounds estimate incremental lifetime cancer risk levels for an individual in a specified population. This unit of risk refers to the cancer risk which is over and above the background cancer risk in unexposed individuals. For example, an incremental lifetime cancer risk level of  $1 \times 10^{-6}$  indicates that, for lifetime exposure, one additional case of cancer may occur per one million exposed individuals.

The incremental lifetime potential cancer risk level to individuals is estimated from the following relationship:

$$ICR = \sum_{i=1}^n CDI_i \times CSF_i \quad \text{EQUATION 6.14}$$

where  $CSF_i$  is the cancer slope factor ( $\text{mg/kg/day}^{-1}$ ) for compound  $i$ , and  $CDI_i$  is the chronic daily intake ( $\text{mg/kg/day}$ ) for compound  $i$ . The cancer slope factor in most instances is the upper 95th percentile confidence limit of the probability of a carcinogenic response based on experimental animal data. The CDI is defined as the exposure expressed as mass of a substance contacted per unit body weight per unit time, averaged over a long period of time (i.e., nine years to a lifetime). The above equation was derived on the basis that cancer is a non-threshold process and that the potential excess risk level is proportional to the cumulative intake over a lifetime.

The above equation is only valid at relatively low risk levels. When estimated risks associated with an exposure pathway are high (i.e., greater than 0.01), the following non-linear equation is used:

$$ICR = \sum_{i=1}^n [1 - \exp\{-CDI \times CSF\}] \quad \text{EQUATION 6.15}$$

The use of the non-linear equation was not necessary for the estimation of potential cancer risks associated with exposures at Site 12 and 13.

In contrast to the above approach for potentially carcinogenic effects, quantitative risk calculations for noncarcinogenic compounds assume that a threshold toxicological effect exists. Therefore, the potential for noncarcinogenic effects are calculated by comparing chronic intake levels with reference doses.



Noncarcinogenic effects are estimated by calculating the Hazard Index (HI) which is defined as:

$$HI = \sum_{i=1}^n HQ_i$$

EQUATION 6.16

where:

$$HQ_i = CDI_i / RfD_i$$

EQUATION 6.17

where  $HQ_i$  is the hazard quotient for chemical  $i$ .  $CDI_i$  is the chronic daily intake (mg/kg/day) of compound  $i$ , and  $RfD_i$  is the reference dose (mg/kg/day) of compound  $i$  over a prolonged period of exposure.

Estimated incremental cancer risks will be compared to the target risk range of  $10^{-4}$  to  $10^{-6}$  which the USEPA considers to be generally acceptable (USEPA, 1989). A value of 1.0 is used for examination of the HI. The hazard index is calculated by comparing estimated chronic daily intakes with threshold levels below which there is minimal potential for noncarcinogenic health effects. Any HI equal to or exceeding 1.0 suggests that noncarcinogenic health effects are possible. HI values below 1.0 suggest that systemic adverse health effects should not occur subsequent to exposure.

The estimated potential risks and hazard indices are discussed by site and media in the following subsections. Base COC determination comparisons, and the subsequent quantitative risk calculations for specific COCs, are provided in Appendix K.

## 6.9 Potential Health Risks from Exposure To COCs

Current and future land-use risks presented in the following sections were calculated due to the contamination detected at Sites 12 and 13. **Tables 6-13 through 6-23** provide the summary of the calculated risk in each site. The tables present only the highest exposed receptor, which is the trespasser population and worker adult in the current scenario, and resident population in the future scenario.

Risk associated with the groundwater pathway future scenario was conservatively calculated for resident population even though this pathway will not be a source of ingestion or dermal contact. The calculated risk assumes a resident child/adult receptor will be exposed to a lesser frequency where a possibility of incidentally tapping into the groundwater, and making it available for contact and ingestion. The exposure frequency would be 14 days per year for resident child, and 28 days per year for resident adult. The complete calculation of risks of all exposed receptor in each site is provided in Appendix K.

### 6.9.1 Site 12

Current and future land-use risks presented in the following sections were calculated due to the contamination detected at Site 12. These calculations were based on the COCs specified in the COC Selection Criteria, provided in **Table 6-1** in Section 6.1.1.

#### 6.9.1.1 Groundwater

**Table 6-13** presents the carcinogenic and noncarcinogenic risks associated with potential future exposure to COCs detected in Site 12's groundwater.

##### Ingestion

###### *Future Scenario*

The total HI for a resident child (3.37) exceeds unity primarily due to 1,2 dichloroethene (total) tetrachloroethene and trichloroethene, suggesting that noncarcinogenic adverse health effects may occur subsequent to ingestion of groundwater. The calculated ICR of 3.28E-04, falls above the acceptable risk range of  $10^{-4}$  to  $10^{-6}$  primarily due to vinyl chloride and tetrachloroethene.

The total HI for a resident adult (2.89) exceeds unity primarily due to 1,2 dichloroethene, tetrachloroethene and trichloroethene. This suggests that systemic health effects may occur subsequent to ingestion of groundwater. The calculated ICR of 1.40E-03 falls above the acceptable risk range of  $10^{-4}$  to  $10^{-6}$  primarily due to vinyl chloride and tetrachloroethene.

##### Dermal Contact

###### *Future Scenario*

The total HI for a resident child (1.27) exceeds unity primarily due to trichloroethene and tetrachloroethene, suggesting that noncarcinogenic adverse health effects may occur subsequent to dermal contact with groundwater. The calculated ICR of 4.35E-05 is within the acceptable risk range of  $10^{-4}$  to  $10^{-6}$ .

The total HI for a resident adult (1.73) exceeds unity due to trichloroethene and tetrachloroethene, suggesting that noncarcinogenic adverse health effects may occur. The calculated ICR of 2.94E-04 exceeds the acceptable risk range of  $10^{-4}$  to  $10^{-6}$  due to tetrachloroethene.

TABLE 6-13

**GROUNDWATER INGESTION, DERMAL CONTACT, AND INHALATION RISKS  
FUTURE SCENARIO**

**SITE 12**

**NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

**Ingestion**

Compound	Resident Child*		Resident Adult*	
	HI	ICR	HI	ICR
Vinyl chloride	--	2.65E-04	--	1.13E-03
1,2-Dichloroethene (total)	1.02E+00	--	8.77E-01	--
Chloroform	2.56E-04	1.34E-09	2.19E-04	5.73E-09
Trichloroethene	9.80E-01	5.55E-06	8.40E-01	2.38E-05
Tetrachloroethene	1.25E+00	5.58E-05	1.07E+00	2.39E-04
Aldrin	1.28E-03	5.59E-08	1.10E-03	2.40E-07
Heptachlor	1.28E-04	2.47E-08	1.10E-04	1.06E-07
alpha-Chlordane	2.11E-03	1.14E-08	1.81E-03	6.06E-08
gamma-Chlordane	1.51E-03	1.01E-08	1.29E-03	4.32E-08
Aluminum	2.99E-04	--	2.56E-04	--
Arsenic	3.67E-02	1.41E-06	3.14E-02	6.06E-06
Barium	2.20E-03	--	1.89E-03	--
Cadmium	1.74E-02	--	1.49E-02	--
Chromium	9.82E-04	--	8.42E-04	--
Cobalt	4.01E-04	--	3.43E-04	--
Iron	3.60E-02	--	3.08E-02	--
Lead	--	--	--	--
Manganese	1.19E-02	--	1.02E-02	--
Nickel	1.29E-03	--	1.10E-03	--
Vanadium	5.19E-04	--	4.45E-04	--
Zinc	7.53E-04	--	6.46E-04	--
TOTAL	3.37E+00	3.28E-04	2.89E+00	1.40E-03

**Dermal Contact**

Compound	Resident Child*		Resident Adult*	
	HI	ICR	HI	ICR
Vinyl chloride	--	3.52E-06	--	2.38E-05
1,2-Dichloroethene (total)	1.86E-02	--	2.52E-02	--
Chloroform	6.05E-05	3.16E-10	8.19E-05	2.14E-09
Trichloroethene	4.10E-01	2.32E-06	5.56E-06	1.57E-05
Tetrachloroethene	8.44E-01	3.76E-05	1.14E+00	2.55E-04
Aldrin	5.96E-06	2.60E-10	8.07E-06	1.76E-09
Heptachlor	4.10E-06	7.90E-10	5.55E-06	5.35E-09
alpha-Chlordane	2.15E-04	1.89E-09	3.38E-04	1.28E-08
gamma-Chlordane	2.02E-04	1.35E-09	2.74E-09	9.15E-09
Aluminum	2.18E-06	--	2.95E-06	--
Arsenic	5.62E-05	2.17E-09	7.61E-05	1.47E-08
Barium	3.20E-05	--	4.34E-06	--

TABLE 6-13 (CONTINUED)

GROUNDWATER INGESTION, DERMAL CONTACT AND INHALATION RISKS  
FUTURE SCENARIO  
SITE 12  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA

Compound	Resident Child*		Resident Adult*	
	HI	ICR	HI	ICR
Cadmium	5.06E-04	--	6.86E-05	--
Chromium	7.15E-06	--	9.68E-06	--
Cobalt	2.92E-06	--	3.95E-06	--
Iron	2.62E-04	--	3.55E-04	--
Lead	--	--	--	--
Manganese	3.46E-04	--	4.68E-04	--
Nickel	4.36E-05	--	5.90E-05	--
Vanadium	2.90E-05	--	3.93E-05	--
Zinc	2.63E-06	--	3.56E-06	--
TOTAL	1.27E+00	4.35E-05	1.73E+00	2.94E-04

Inhalation

Compound	Resident Child*		Resident Adult*	
	HI	ICR	HI	ICR
Vinyl chloride	NA	1.93E-04	NA	4.13E-04
1,2-Dichloroethene (total)	NA	--	NA	--
Chloroform	NA	6.28E-08	NA	1.35E-07
Trichloroethene	NA	1.27E-05	NA	2.73E-05
Tetrachloroethene	NA	7.05E-06	NA	1.51E-05
TOTAL		2.12E-04		4.55E-04

\*Exposed as recreational trespasser

HI - Hazard Index

ICR - Incremental Cancer Risk

## Inhalation

### *Future Scenario*

Due to unavailable reference doses of the COCs by inhalation, an HI was not calculated for a resident child. The calculated ICR of  $2.12\text{E-}04$  for a resident child is above the USEPA's acceptable risk range of  $10^{-4}$  to  $10^{-6}$  primarily due to vinyl chloride.

Due to unavailable reference doses of the COCs by inhalation, an HI was not calculated for a resident adult. The calculated ICR of  $4.55\text{E-}04$  for a resident adult falls above the acceptable risk range of  $10^{-4}$  to  $10^{-6}$  primarily due to vinyl chloride.

### 6.9.1.2 Surface Water

**Table 6-14** presents the carcinogenic and noncarcinogenic risks associated with potential current exposure to COCs. **Table 6-15** presents the carcinogenic and noncarcinogenic risks associated with potential future exposure to COCs detected in Site 12 surface waters.

## Ingestion

### *Current Scenario*

The total HI for a trespasser child (68.3) exceeds unity due to the presence of aluminum, arsenic, cadmium, chromium, iron, vanadium and zinc. This suggests that systemic health effects may occur subsequent to exposure. The ICR for a child exposed incidentally to surface water was  $2.81\text{E-}04$ . This level exceeds USEPA's target cancer risk range of  $10^{-4}$  to  $10^{-6}$ .

The total HI for a trespasser adult (14.6) exceeds unity due to aluminum and iron. This suggests that systemic health effects may occur subsequent to exposure. The ICR calculated for a trespasser adult exposed to surface water via ingestion was  $3.01\text{E-}04$  due to arsenic and beryllium, which falls above USEPA's target cancer risk range.

The total HI for a worker adult (10.5) exceeds unity due to aluminum and iron. This suggests systemic health effects may occur subsequent to exposure. The ICR for a worker adult exposed incidentally to surface water was  $1.79\text{E-}04$ , which falls above the USEPA's target cancer risk range due primarily to arsenic and beryllium.

### *Future Scenario*

The total HI for a resident child (68.3) exceeds unity due to aluminum, arsenic, cadmium, chromium, iron, vanadium and zinc. This suggests that systemic health effects may occur subsequent to exposure. The ICR for a child exposed incidentally to surface water was  $2.81\text{E-}04$  due to arsenic and beryllium. This level exceeds USEPA's target cancer risk range of  $10^{-4}$  to  $10^{-6}$ .

TABLE 6-14

**SURFACE WATER INGESTION AND DERMAL CONTACT RISKS  
CURRENT SCENARIO  
SITE 12  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

**Ingestion**

Compound	Trespasser Child		Trespasser Adult		Worker Adult	
	HI	ICR	HI	ICR	HI	ICR
1,2-Dichloroethene (total)	9.63E-02	--	2.06E-02	--	1.47E-02	--
Trichloroethene	6.39E-02	3.62E-07	1.37E-02	3.87E-07	9.78E-03	2.31E-07
Tetrachloroethene	3.84E-02	1.71E-06	8.22E-03	1.83E-06	5.87E-03	1.09E-06
Aluminum	1.05E+01	--	2.24E+00	--	1.60E+00	--
Arsenic	4.62E+00	1.78E-04	9.91E-01	1.91E-04	7.08E-01	1.14E-04
Barium	8.66E-01	--	1.86E-01	--	1.33E-01	--
Beryllium	4.45E-02	1.00E-04	1.17E-02	1.08E-04	8.34E-03	6.40E-05
Cadmium	1.17E+00	--	2.52E-01	--	1.80E-01	--
Chromium	3.18E+00	--	6.82E-01	--	4.87E-01	--
Cobalt	5.72E-02	--	1.23E-02	--	8.75E-03	--
Copper	9.75E-01	--	2.09E-01	--	1.49E-01	--
Iron	4.04E+01	--	8.66E+00	--	6.18E+00	--
Manganese	8.98E-01	--	1.92E-01	--	1.37E-01	--
Mercury	1.32E-01	--	2.83E-02	--	2.02E-02	--
Nickel	7.05E-01	--	1.51E-01	--	1.08E-01	--
Vanadium	2.96E+00	--	6.34E-01	--	4.53E-01	--
Zinc	1.62E+00	--	3.47E-01	--	2.48E-01	--
<b>TOTAL</b>	<b>6.83E+01</b>	<b>2.81E-04</b>	<b>1.46E+01</b>	<b>3.01E-04</b>	<b>1.05E+01</b>	<b>1.79E-04</b>

**Dermal Contact**

Compound	Trespasser Child		Trespasser Adult		Worker Adult	
	HI	ICR	HI	ICR	HI	ICR
1,2-Dichloroethene (total)	1.14E-02	--	7.71E-03	--	5.51E-03	--
Trichloroethene	1.74E-01	4.93E-06	1.18E-01	3.58E-06	8.41E-02	1.98E-06
Tetrachloroethene	1.68E-01	3.75E-05	1.14E-01	2.54E-05	8.12E-02	1.51E-05
Aluminum	4.95E-01	--	3.35E-01	--	2.39E-01	--
Arsenic	4.61E-02	8.89E-06	3.12E-02	6.02E-06	2.23E-02	3.58E-06
Barium	8.20E-03	--	5.55E-03	--	3.96E-03	--
Beryllium	5.16E-02	4.75E-04	3.49E-02	3.22E-04	2.48E-02	1.91E-04
Cadmium	2.22E-01	--	1.50E-01	--	1.07E-01	--
Chromium	1.51E-01	--	1.02E-01	--	7.28E-02	--
Cobalt	2.71E-03	--	1.83E-03	--	1.31E-03	--
Copper	1.54E-02	--	1.04E-02	--	7.44E-03	--
Iron	1.91E+00	--	1.29E+00	--	9.25E-01	--
Manganese	1.71E-01	--	1.15E-01	--	8.22E-02	--
Mercury	8.34E-03	--	5.64E-03	--	4.03E-03	--
Nickel	1.55E-01	--	1.05E-01	--	7.51E-02	--
Vanadium	1.08E+00	--	7.29E-01	--	5.21E-01	--

**TABLE 6-14 (CONTINUED)**

**SURFACE WATER INGESTION AND DERMAL CONTACT RISKS  
CURRENT SCENARIO  
SITE 12  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

Compound	Trespasser Child		Trespasser Adult		Worker Adult	
	HI	ICR	HI	ICR	HI	ICR
Zinc	3.68E-02	--	2.49E-02	--	1.78E-02	--
TOTAL	4.70E+00	5.27E-04	3.18E+00	3.57E-05	2.27E+00	2.12E-04

HI - Hazard Index

ICR - Incremental Cancer Risk

TABLE 6-15

**SURFACE WATER INGESTION AND DERMAL CONTACT RISKS  
FUTURE SCENARIO  
SITE 12  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

**Ingestion**

Compound	Resident Child		Resident Adult	
	HI	ICR	HI	ICR
1,2-Dichloroethene	9.63E-02	--	2.06E-02	--
Trichloroethene	6.39E-02	3.62E-07	1.37E-02	3.87E-07
Tetrachloroethene	3.84E-02	1.71E-06	8.22E-03	1.83E-06
Aluminum	1.05E+01	--	2.24E+00	--
Arsenic	4.62E+00	1.78E-04	9.91E-01	1.91E-04
Barium	8.66E-01	--	1.86E-01	--
Beryllium	5.45E-02	1.00E-04	1.17E-02	1.08E-04
Cadmium	1.17E+00	--	2.52E-01	--
Chromium	3.18E+00	--	6.82E-01	--
Cobalt	5.72E-02	--	1.23E-02	--
Copper	9.75E-01	--	2.09E-01	--
Iron	4.04E+01	--	8.66E+00	--
Manganese	8.98E-01	--	1.92E-01	--
Mercury	1.32E-01	--	2.83E-02	--
Nickel	7.05E-01	--	1.51E-01	--
Vanadium	2.96E+00	--	6.34E-01	--
Zinc	1.62E+00	--	3.47E-01	--
TOTAL	6.83E+01	2.81E-04	1.46E+01	3.01E-04

**Dermal Contact**

Compound	Resident Child		Resident Adult	
	HI	ICR	HI	ICR
1,2-Dichloroethene	1.14E-02	--	7.71E-03	--
Trichloroethene	1.74E-01	9.84E-07	1.18E-01	3.33E-06
Tetrachloroethene	1.68E-01	7.48E-06	1.14E-01	2.53E-05
Aluminum	4.95E-01	--	3.35E-01	--
Arsenic	4.61E-02	1.78E-06	3.12E-02	6.02E-06
Barium	8.20E-03	--	5.55E-03	--
Beryllium	5.16E-02	9.50E-05	3.49E-02	3.22E-04
Cadmium	2.22E-01	--	1.51E-01	--
Chromium	1.51E-01	-	1.02E-01	--
Cobalt	2.71E-03	--	1.83E-03	--
Copper	1.54E-02	--	1.04E-02	--
Iron	1.91E+00	--	1.29E+00	--
Manganese	1.71E-01	--	1.15E-01	--
Mercury	8.34E-03	--	5.64E-03	--
Nickel	1.55E-01	--	1.05E-01	--
Vanadium	1.08E-00	--	7.29E-01	--



**TABLE 6-15 (CONTINUED)**

**SURFACE WATER INGESTION AND DERMAL CONTACT RISKS  
FUTURE SCENARIO  
SITE 12  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

Compound	Resident Child		Resident Adult	
	HI	ICR	HI	ICR
Zinc	3.68E-02	--	2.49E-02	--
TOTAL	4.70E+00	1.05E-04	3.18E+00	3.56E-04

HI - Hazard Index

ICR - Incremental Cancer Risk

The total HI for a resident adult (14.6) exceeds unity due to aluminum and iron. This suggests that systemic health effects may be expected to occur subsequent to exposure. The ICR calculated for a resident adult exposed to surface water via ingestion was 3.01E-04 due to the presence of arsenic and beryllium, which falls above USEPA's target cancer risk range.

### Dermal Contact

#### *Current Scenario*

The total HI for a trespasser child (4.70) is above unity due to trichloroethene, tetrachloroethene, iron, aluminum, cadmium, nickel, manganese, chromium and vanadium suggesting that noncarcinogenic adverse health effects may occur subsequent to dermal contact with surface water. The calculated ICR, 5.27E-04, falls above USEPA's acceptable risk range of  $10^{-4}$  to  $10^{-6}$  primarily due to beryllium and tetrachloroethene.

The total HI for a trespasser adult (3.18) was above unity, suggesting that noncarcinogenic adverse health effects will occur this is primarily due to iron, vanadium, aluminum, nickel, manganese, chromium, trichloroethene and tetrachloroethene. The calculated ICR of 3.57E-04 falls above the acceptable risk range of  $10^{-4}$  to  $10^{-6}$  due to beryllium.

The total HI for a worker adult (2.27) was above unity, suggesting that noncarcinogenic adverse health effects will occur subsequent to dermal contact with surface water. This is primarily due to aluminum, cadmium, iron, vanadium. The calculated ICR (2.12E-04), falls above the acceptable risk range due to beryllium.

#### *Future Scenario*

The total HI for a resident child (4.70) is above unity due to trichloroethene, tetrachloroethene, iron, aluminum, cadmium, nickel, vanadium and manganese, suggesting that noncarcinogenic adverse health effects may occur subsequent to dermal contact with surface water. The calculated ICR, 1.05E-04, falls above the acceptable risk range of  $10^{-4}$  to  $10^{-6}$  due to the presence of beryllium, arsenic and tetrachloroethene.

The total HI for a resident adult (3.08) was above unity, suggesting that noncarcinogenic adverse health effects may occur. This is primarily due to trichloroethene, tetrachloroethene, aluminum, cadmium, chromium, iron, manganese, nickel and vanadium. The calculated ICR of 3.56E-04 falls above the acceptable risk range of  $10^{-4}$  to  $10^{-6}$  due to beryllium.

### 6.9.1.3 Sediment

**Table 6-16** presents the carcinogenic and noncarcinogenic risks associated with potential current exposure to COCs. **Table 6-17** presents the carcinogenic and noncarcinogenic risks associated with potential future exposure to COCs detected in Site 12 sediments.

TABLE 6-16

**SEDIMENT INGESTION AND DERMAL CONTACT RISKS  
CURRENT SCENARIO  
SITE 12  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

**Ingestion**

Compound	Trespasser Child		Trespasser Adult		Worker Adult	
	HI	ICR	HI	ICR	HI	ICR
1,2-Dichloroethene	7.26E-07	--	1.55E-07	--	6.94E-07	--
Trichloroethene	1.09E-06	6.14E-12	2.33E-07	6.58E-12	1.04E-06	2.45E-11
Tetrachloroethene	5.28E-07	2.35E-11	1.13E-07	2.52E-11	5.05E-07	9.38E-11
Toluene	1.28E-08	--	2.74E-09	--	1.22E-08	--
Aluminum	3.56E-03	--	7.63E-04	--	3.41E-03	--
Arsenic	1.28E-02	4.93E-07	2.74E-03	5.28E-07	1.22E-02	1.97E-06
Barium	3.75E-04	--	8.04E-05	--	3.59E-04	--
Beryllium	2.86E-05	5.28E-08	6.14E-06	5.65E-08	2.74E-05	2.10E-07
Cadmium	1.23E-03	--	2.63E-04	--	1.17E-03	--
Chromium	1.26E-03	--	2.70E-04	--	1.21E-03	--
Cobalt	2.34E-05	--	5.02E-06	--	2.24E-05	--
Copper	4.22E-04	--	9.04E-05	--	4.03E-04	--
Iron	1.28E-02	--	2.75E-03	--	1.23E-02	--
Manganese	3.91E-04	--	8.38E-05	--	3.74E-04	--
Mercury	2.90E-04	--	6.21E-05	--	2.77E-04	--
Nickel	1.95E-04	--	4.18E-05	--	1.87E-04	--
Vanadium	1.35E-03	--	2.90E-04	--	1.30E-03	--
Zinc	6.53E-04	--	1.40E-04	--	6.25E-04	--
<b>TOTAL</b>	<b>3.54E-02</b>	<b>5.46E-07</b>	<b>7.59E-03</b>	<b>5.85E-07</b>	<b>3.39E-02</b>	<b>2.18E-06</b>

**Dermal Contact**

Compound	Trespasser Child		Trespasser Adult		Worker Adult	
	HI	ICR	HI	ICR	HI	ICR
1,2-Dichloroethene	2.06E-06	--	2.82E-06	--	2.52E-05	--
Trichloroethene	3.09E-06	1.75E-11	4.21E-06	1.19E-10	3.76E-05	8.87E-10
Tetrachloroethene	1.50E-06	6.69E-11	2.05E-06	4.57E-10	1.83E-05	3.40E-09
Toluene	3.64E-08	--	4.96E-08	--	4.43E-07	--
Aluminum	1.62E-03	--	2.21E-03	--	1.98E-02	--
Arsenic	3.67E-03	1.42E-07	5.02E-03	9.69E-07	4.48E-02	7.20E-06
Barium	3.42E-05	--	4.66E-05	--	4.46E-04	--
Beryllium	2.61E-04	4.80E-07	3.56E-04	3.28E-06	3.18E-03	2.44E-05
Cadmium	4.47E-03	--	6.10E-03	--	5.45E-02	--
Chromium	5.74E-04	--	7.84E-04	--	7.00E-03	--
Cobalt	1.07E-05	--	1.46E-05	--	1.30E-04	--
Copper	6.40E-05	--	8.73E-05	--	7.80E-04	--
Iron	5.84E-03	--	7.97E-03	--	7.12E-02	--
Manganese	7.12E-04	--	9.72E-04	--	8.68E-03	--
Mercury	1.76E-04	--	2.40E-04	--	2.14E-03	--

**TABLE 6-16 (CONTINUED)**

**SEDIMENT INGESTION AND DERMAL CONTACT RISKS  
CURRENT SCENARIO  
SITE 12  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

Compound	Trespasser Child		Trespasser Adult		Worker Adult	
	HI	ICR	HI	ICR	HI	ICR
Nickel	4.13E-04	--	5.64E-04	--	5.04E-03	--
Vanadium	4.74E-03	--	6.47E-03	--	5.98E-02	--
Zinc	2.38E-04	--	3.25E-04	--	2.90E-03	--
TOTAL	2.28E-02	6.22E-07	3.12E-02	4.25E-06	2.78E-01	3.16E-05

HI - Hazard Index

ICR - Incremental Cancer Risk

TABLE 6-17

**SEDIMENT INGESTION AND DERMAL CONTACT RISKS  
FUTURE SCENARIO  
SITE 12  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

**Ingestion**

Compound	Resident Child		Resident Adult	
	HI	ICR	HI	ICR
1,2-Dichloroethene	1.81E-05	--	1.94E-06	--
Trichloroethene	2.71E-05	1.53E-10	2.91E-06	8.22E-11
Tetrachloroethene	1.32E-05	5.88E-10	1.41E-06	3.15E-10
Toluene	3.20E-07	--	3.42E-08	--
Aluminum	8.90E-02	--	9.54E-03	--
Arsenic	3.20E-01	1.23E-05	3.42E-02	6.60E-06
Barium	9.38E-03	--	1.01E-03	--
Beryllium	7.16E-04	1.32E-06	7.67E-05	7.07E-07
Cadmium	3.07E-02	--	3.29E-03	--
Chromium	3.15E-02	--	3.38E-03	--
Cobalt	5.86E-04	--	6.28E-05	--
Copper	1.05E-02	--	1.13E-03	--
Iron	3.21E-01	--	3.44E-02	--
Manganese	9.78E-03	--	1.05E-03	--
Mercury	7.25E-03	--	7.76E-04	--
Nickel	4.88E-03	--	5.23E-04	--
Vanadium	3.38E-02	--	3.63E-03	--
Zinc	1.63E-02	--	1.75E-03	--
TOTAL	8.85E-01	1.36E-05	9.48E-02	7.31E-06

**Dermal Contact**

Compound	Resident Child		Resident Adult	
	HI	ICR	HI	ICR
1,2-Dichloroethene	5.16E-05	--	3.49E-05	--
Trichloroethene	7.71E-05	4.36E-10	5.22E-05	1.49E-09
Tetrachloroethene	3.75E-05	1.61E-09	2.54E-05	5.67E-09
Toluene	9.09E-07	--	6.16E-07	--
Aluminum	4.05E-02	--	2.74E-02	--
Arsenic	9.19E-02	3.54E-06	6.22E-02	1.20E-05
Barium	8.54E-04	--	5.78E-04	--
Beryllium	6.52E-03	1.20E-05	4.41E-03	4.07E-05
Cadmium	1.12E-01	--	7.56E-02	--
Chromium	1.43E-02	--	9.72E-03	--
Cobalt	2.67E-09	--	1.81E-04	--
Copper	1.60E-03	--	1.08E-03	--
Iron	1.46E-01	--	9.88E-02	--
Manganese	1.78E-02	--	1.21E-02	--
Mercury	4.40E-03	--	2.98E-03	--

**TABLE 6-17 (CONTINUED)**

**SEDIMENT INGESTION AND DERMAL CONTACT RISKS  
FUTURE SCENARIO  
SITE 12  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

Compound	Resident Child		Resident Adult	
	HI	ICR	HI	ICR
Nickel	1.03E-02	--	6.99E-03	--
Vanadium	1.18E-01	--	8.02E-02	--
Zinc	5.94E-03	--	4.02E-03	--
TOTAL	5.71E-01	1.56E-05	3.86E-01	5.27E-05

HI - Hazard Index

ICR - Incremental Cancer Risk

## Ingestion

### *Current Scenario*

The total HI for a trespasser child (0.035) falls below unity. This suggests that systemic health effects may not occur subsequent to exposure. The ICR for a child exposed incidentally to sediment was  $5.46\text{E-}07$ . This level falls below USEPA's target cancer risk range of  $10^{-4}$  to  $10^{-6}$ .

The total HI for a trespasser adult (0.00759) also falls below unity. The ICR calculated for a trespasser adult exposed to sediment via ingestion was  $5.85\text{E-}07$ , which falls below USEPA's target cancer risk range.

The total HI for a worker adult (0.0339) does not exceed unity. This suggests systemic health effects may not be expected to occur subsequent to exposure. The ICR for a worker adult exposed incidentally to sediment was  $2.18\text{E-}06$ , which falls within USEPA's target cancer risk range.

### *Future Scenario*

The total HI for a resident child (0.885) is below unity. This suggests that systemic health effects may not occur subsequent to exposure. The ICR for a child exposed incidentally to sediment was  $1.36\text{E-}05$ . This level falls within USEPA's target cancer risk range of  $10^{-4}$  to  $10^{-6}$ .

The total HI for a resident adult (0.0948) falls below unity. The ICR calculated for a resident adult exposed to sediment via ingestion was  $7.31\text{E-}06$ , which falls within USEPA's target cancer risk range.

## Dermal Contact

### *Current Scenario*

The total HI for a trespasser child (0.0228) falls below unity, suggesting that noncarcinogenic adverse health effects may not occur subsequent to dermal contact with sediment. The calculated ICR,  $6.22\text{E-}07$ , falls below the acceptable risk range of  $10^{-4}$  to  $10^{-6}$ .

The total HI for a trespasser adult (0.0312) was also below unity, suggesting that noncarcinogenic adverse health effects may not occur. The calculated ICR of  $4.25\text{E-}06$  falls within USEPA's acceptable risk range of  $10^{-4}$  to  $10^{-6}$ .

The total HI for a worker adult (0.0271) was also below unity, suggesting that noncarcinogenic adverse health effects may not occur subsequent to dermal contact with sediment. The calculated ICR,  $3.16\text{E-}05$ , falls within EPA's acceptable risk range.

### *Future Scenario*

The total HI for a resident child (0.571) falls below unity, suggesting that noncarcinogenic adverse health effects may not occur subsequent to dermal contact with sediment. The calculated ICR,  $1.56\text{E-}05$ , falls within the USEPA acceptable risk range of  $10^{-4}$  to  $10^{-6}$ .

The total HI for a resident adult (0.386) was also below unity, suggesting that noncarcinogenic adverse health effects will not occur. The calculated ICR of  $5.27\text{E-}05$  falls within the USEPA acceptable risk range of  $10^{-4}$  to  $10^{-6}$ .

#### 6.9.1.4 Fish

**Table 6-18** presents the carcinogenic and noncarcinogenic risks associated with potential future exposure to COCs from fish ingestion found in Site 12 surface waters.

#### Ingestion

### *Future Scenario*

The total HI for a resident child (8.33) exceeds unity due to the accumulation of arsenic and mercury in fish tissue. This suggests that systemic health effects may occur subsequent to exposure. The ICR for a child ingesting fish was  $6.42\text{E-}05$ . This level falls within USEPA's target cancer risk range of  $10^{-4}$  to  $10^{-6}$ .

The total HI for a resident adult (1.78) also exceeds unity again due to the accumulation of arsenic and mercury. The ICR calculated for a resident adult ingesting fish was  $6.88\text{E-}05$ , which falls within USEPA's target cancer risk range.

#### 6.9.1.5 Subsurface Soil

**Table 6-19** presents the carcinogenic and noncarcinogenic risks associated with potential future exposure to COCs detected in Site 12 subsurface soils.

#### Ingestion

### *Future Scenario*

The total HI for a resident child (1.11) exceeds unity due to the presence of arsenic and iron. This suggests that systemic health effects may occur subsequent to exposure. The ICR for a child ingesting soil was  $6.36\text{E-}06$ . This level was within USEPA's target cancer risk range of  $10^{-4}$  to  $10^{-6}$ .

The total HI for a resident adult (0.118) was below unity, suggesting that noncarcinogenic adverse health effects will not occur. The calculated ICR,  $3.41\text{E-}06$ , falls within the USEPA acceptable risk range of  $10^{-4}$  to  $10^{-6}$ .



**TABLE 6-18**

**FISH INGESTION RISKS**  
**FUTURE SCENARIO**  
**SITE 12**  
**NAVAL AMPHIBIOUS BASE - LITTLE CREEK**  
**VIRGINIA BEACH, VIRGINIA**

**Ingestion**

Compound	Resident Child		Resident Adult	
	HI	ICR	HI	ICR
Tetrachloroethene	3.86E-03	1.72E-07	8.28E-04	1.85E-07
Arsenic	1.43E+00	5.50E-05	3.06E-01	5.90E-05
Beryllium	4.89E-03	9.02E-06	1.05E-03	9.66E-06
Copper	6.83E-01	0.00E+00	1.36E-01	0.00E+00
Mercury	6.01E+00	0.00E+00	1.29E+00	0.00E+00
Zinc	2.48E-01	0.00E+00	5.31E-02	0.00E+00
<b>TOTAL</b>	<b>8.33E+00</b>	<b>6.42E-05</b>	<b>1.78E+00</b>	<b>6.88E-05</b>

HI - Hazard Index

ICR - Incremental Cancer Risk

TABLE 6-19

**SUBSURFACE SOIL INGESTION AND DERMAL CONTACT RISKS  
FUTURE SCENARIO  
SITE 12  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

**Ingestion**

Compound	Resident Child		Resident Adult	
	HI	ICR	HI	ICR
Toluene	2.56E-07	--	2.74E-08	--
Tetrachloroethene	9.46E-06	4.22E-10	1.01E-06	2.26E-10
Benzo(a)anthracene	--	2.88E-08	--	1.54E-08
Benzo(b)fluoranthene	--	5.76E-08	--	3.09E-08
Benzo(k)fluoranthene	--	3.92E-09	--	2.10E-09
Benzo(a)pyrene	--	2.88E-07	--	1.54E-07
Heptachlor	2.25E-05	4.34E-09	2.41E-06	2.32E-09
4,4'-DDT	8.80E-05	1.28E-09	9.42E-06	6.87E-10
alpha-Chlordane	1.94E-03	1.30E-08	2.08E-04	6.95E-09
gamma-Chlordane	2.07E-03	1.38E-08	2.21E-04	7.40E-09
Arsenic	1.54E-01	5.95E-06	1.65E-02	3.19E-06
Barium	9.63E-03	--	1.03E-03	--
Chromium	5.57E-02	--	5.97E-03	--
Cobalt	1.09E-03	--	1.16E-04	--
Copper	2.30E-03	--	2.47E-04	--
Iron	8.10E-01	--	8.68E-02	--
Lead	--	--	--	--
Nickel	6.35E-03	--	6.80E-04	--
Vanadium	6.27E-02	--	6.72E-03	--
TOTAL	1.11E+00	6.36E-06	1.18E-01	3.41E-06

**Dermal Contact**

Compound	Resident Child		Resident Adult	
	HI	ICR	HI	ICR
Toluene	7.27E-07	--	4.97E-07	--
Tetrachloroethene	2.69E-05	1.20E-09	1.84E-05	4.09E-09
Benzo(a)anthracene	--	5.24E-08	--	1.79E-07
Benzo(b)fluoranthene	--	1.05E-07	--	3.58E-07
Benzo(k)fluoranthene	--	7.13E-09	--	2.44E-08
Benzo(a)pyrene	--	5.24E-07	--	1.79E-06
Heptachlor	2.46E-05	4.74E-09	1.68E-05	1.62E-08
4,4'-DDT	9.61E-05	1.40E-09	6.56E-05	4.78E-09
alpha-Chlordane	2.12E-03	1.92E-08	1.45E-03	4.83E-08
gamma-Chlordane	2.26E-03	1.57E-08	1.54E-03	5.15E-08
Arsenic	4.43E-02	1.71E-06	3.03E-02	5.84E-06
Barium	8.76E-04	--	5.98E-04	--
Chromium	2.53E-02	--	1.73E-02	--
Cobalt	4.94E-04	--	3.38E-04	--

**TABLE 6-19 (CONTINUED)**

**SUBSURFACE SOIL INGESTION AND DERMAL CONTACT RISKS  
FUTURE SCENARIO  
SITE 12  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

Compound	Resident Child		Resident Adult	
	HI	ICR	HI	ICR
Copper	3.49-04	--	2.38E-04	--
Iron	3.68E-01	--	2.52E-01	--
Lead	--	--	--	--
Nickel	1.34E-02	--	9.17E-03	--
Vanadium	2.19E-01	--	1.50E-01	--
TOTAL	6.77E-012	2.44E-06	4.62E-01	8.31E-06

HI - Hazard Index

ICR - Incremental Cancer Risk

## Dermal Contact

### *Future Scenario*

The total HI for a resident child (0.677) falls below unity suggesting that noncarcinogenic adverse health effects will not occur subsequent to dermal contact with subsurface soil. The calculated ICR,  $2.44\text{E-}06$ , falls within the USEPA acceptable risk range of  $10^{-4}$  to  $10^{-6}$ .

The total HI for a resident adult (0.462) also falls below unity suggesting that noncarcinogenic adverse health effects will not occur. The calculated ICR of  $8.31\text{E-}06$  falls within the USEPA's acceptable risk range of  $10^{-4}$  to  $10^{-6}$ .

### **6.9.2 Site 13**

Current and future land-use risks presented in the following sections were calculated due to the contamination detected at Site 13. These calculations were based on the COCs specified in the COC Selection Criteria provided in **Table 6-2** in Section 6.1.1.

#### **6.9.2.1**      Surface Soil

**Table 6-20** presents the carcinogenic and noncarcinogenic risks associated with potential current exposure to COCs, and **Table 6-21** presents the carcinogenic and noncarcinogenic risks associated with potential future exposure to COCs detected in surface soil at Site 13.

## Ingestion

### *Current Scenario*

The total HI for a trespasser child (0.000477) falls well below unity. This suggests that systemic health effects are not expected to occur subsequent to exposure. The ICR for a child exposed incidentally to soil was  $3.00\text{E-}06$ , falls within USEPA's target cancer risk range of  $10^{-4}$  to  $10^{-6}$ .

The total HI for a trespasser adult (0.000102) falls well below unity. This suggests that systemic health effects are not expected to occur subsequent to exposure. The ICR for a trespasser adult exposed incidentally to soil was  $3.22\text{E-}06$ , and falls within USEPA's target cancer risk range of  $10^{-4}$  to  $10^{-6}$ .

The total HI for a worker adult (0.000457) falls well below unity. This suggests that systemic health effects are not expected to occur subsequent to exposure. The ICR for a worker adult exposed incidentally to soil was  $1.20\text{E-}05$ , and falls within USEPA's target cancer risk range of  $10^{-4}$  to  $10^{-6}$ .

TABLE 6-20

**SURFACE SOIL INGESTION AND DERMAL CONTACT RISKS  
CURRENT SCENARIO**

**SITE 13**

**NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

**Ingestion**

Compound	Trespasser Child		Trespasser Adult		Worker Adult	
	HI	ICR	HI	ICR	HI	ICR
2-Methylnaphthalene	5.24E-06	--	1.12E-06	--	5.01E-06	--
Dibenzofuran	1.11E-04	--	2.38E-05	--	1.06E-04	--
Pentachlorophenol	2.22E-04	6.84E-08	4.75E-05	7.33E-08	2.12E-04	2.73E-07
Phenanthrene	1.39E-04	--	2.99E-05	--	1.33E-04	--
Benzo(a)anthracene	--	3.20E-07	--	3.43E-07	--	1.28E-06
Benzo(b)fluoranthene	--	4.16E-07	--	4.46E-07	--	1.66E-06
Benzo(a)pyrene	--	2.05E-06	--	2.19E-06	--	8.16E-06
Indeno(1,2,3-cd)pyrene	--	1.28E-07	--	1.37E-07	--	5.10E-07
Benzo(g,h,i)perylene	--	2.45E-08	--	2.62E-08	--	9.75E-08
<b>Total</b>	<b>4.77E-04</b>	<b>3.00E-06</b>	<b>1.02E-04</b>	<b>3.22E-06</b>	<b>4.57E-04</b>	<b>1.20E-05</b>

**Dermal Contact**

Compound	Trespasser Child		Trespasser Adult		Worker Adult	
	HI	ICR	HI	ICR	HI	ICR
2-Methylnaphthalene	9.54E-06	--	1.30E-05	--	1.16E-04	--
Dibenzofuran	2.02E-04	--	2.76E-04	--	2.47E-03	--
Pentachlorophenol	4.03E-04	1.24E-07	5.51E-04	8.50E-07	4.92E-03	6.32E-06
Phenanthrene	1.51E-04	--	2.06E-04	--	1.84E-03	--
Benzo(a)anthracene	--	5.82E-07	--	3.98E-06	--	2.96E-05
Benzo(b)fluoranthene	--	7.57E-07	--	5.17E-06	--	3.85E-05
Benzo(a)pyrene	--	3.73E-06	--	2.55E-05	--	1.89E-04
Indeno(1,2,3-cd)pyrene	--	2.33E-01	--	1.59E-06	--	1.18E-05
Benzo(g,h,i)perylene	--	4.45E-08	--	3.04E-07	--	2.26E-06
<b>Total</b>	<b>7.66E-04</b>	<b>5.47E-06</b>	<b>1.05E-03</b>	<b>3.73E-05</b>	<b>9.34E-03</b>	<b>2.78E-04</b>

HI - Hazard Index

ICR - Incremental Cancer Risk

TABLE 6-21

**SURFACE SOIL INGESTION AND DERMAL CONTACT RISKS  
FUTURE SCENARIO  
SITE 13  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

**Ingestion**

Compound	Resident Child		Resident Adult	
	HI	ICR	HI	ICR
2-Methylnaphthalene	1.31E-04	--	1.40E-05	--
Dibenzofuran	2.78E-03	--	2.98E-04	--
Pentachlorophenol	5.54E-03	1.71E-06	5.94E-04	9.16E-07
Phenanthrene	3.48E-03	--	3.73E-04	--
Benzo(a)anthracene	--	8.00E-06	--	4.29E-06
Benzo(b)fluoranthene	--	1.04E-05	--	4.57E-06
Benzo(a)pyrene	--	5.12E-05	--	2.74E-05
Indeno(1,2,3-cd)pyrene	--	3.20E-06	--	1.71E-06
Benzo(g,h,i)perylene	--	6.12E-07	--	3.28E-07
<b>Total</b>	<b>1.19E-02</b>	<b>7.51E-05</b>	<b>1.28E-03</b>	<b>4.02E-05</b>

**Dermal Contact**

Compound	Resident Child		Resident Adult	
	HI	ICR	HI	ICR
2-Methylnaphthalene	2.39E-04	--	1.63E-04	--
Dibenzofuran	5.06E-03	--	3.46E-03	--
Pentachlorophenol	1.01E-02	3.11E-06	6.89E-03	1.07E-05
Phenanthrene	3.77E-03	--	2.58E-03	--
Benzo(a)anthracene	--	1.46E-05	--	4.97E-05
Benzo(b)fluoranthene	--	1.89E-05	--	6.46E-05
Benzo(a)pyrene	--	9.32E-05	--	3.18E-04
Indeno(1,2,3-cd)pyrene	--	5.82E-06	--	1.99E-05
Benzo(g,h,i)perylene	--	1.11E-06	--	3.80E-06
<b>Total</b>	<b>1.92E-02</b>	<b>1.37E-04</b>	<b>1.31E-02</b>	<b>4.64E-04</b>

HI - Hazard Index

ICR - Incremental Cancer Risk

### *Future Scenario*

The total HI for a resident child (0.0119) falls well below unity. This suggests that systemic health effects are not expected to occur subsequent to exposure. The ICR for a child exposed incidentally to soil was 7.51E-05, and falls within USEPA's target cancer risk range of  $10^{-4}$  to  $10^{-6}$ .

The total HI for a resident adult (0.00128) falls well below unity. This suggests that systemic health effects are not expected to occur subsequent to exposure. The ICR for a resident adult exposed incidentally to soil was 4.02E-05, and falls within USEPA's target cancer risk range of  $10^{-4}$  to  $10^{-6}$ .

### Dermal Contact

#### *Current Scenario*

The total HI for a trespasser child (0.000766) falls well below unity. This suggests that systemic health effects are not expected to occur subsequent to exposure. The ICR for child exposed incidentally to soil was 5.47E-06, and falls within USEPA's target cancer risk range of  $10^{-4}$  to  $10^{-6}$ .

The total HI for a trespasser adult (0.00105) falls well below unity. This suggests that systemic health effects are not expected to occur subsequent to exposure. The ICR for a resident adult exposed incidentally to soil was 3.73E-05 and falls within USEPA's target cancer risk range of  $10^{-4}$  to  $10^{-6}$ .

The total HI for a worker adult (0.00934) falls well below unity. This suggests that systemic health effects are not expected to occur subsequent to exposure. The ICR for a worker adult exposed incidentally to soil was 2.78E-04, which falls above the USEPA's target cancer risk range of  $10^{-4}$  to  $10^{-6}$  primarily due to benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene and indeno(1,2,3-cd) perylene.

#### *Future Scenario*

The total HI for a resident child (0.0192) falls well below unity. This suggests that systemic health effects are not expected to occur subsequent to exposure. The ICR for a child exposed incidentally to soil was 1.37E-04, which falls above the USEPA's target cancer risk range of  $10^{-4}$  to  $10^{-6}$  due to benzo(a)pyrene, benzo(b)fluoranthene, benzo(a)anthracene.

The total HI for a resident adult (0.0131) falls well below unity. This suggests that systemic health effects are not expected to occur subsequent to exposure. The ICR for a resident adult exposed incidentally to soil was 4.64E-04, which falls above the USEPA's target cancer risk range of  $10^{-4}$  to  $10^{-6}$  due to benzo(a)pyrene, benzo(b)fluoranthene, and benzo(a)anthracene.

#### 6.9.2.2 Subsurface Soil

**Table 6-22** presents the carcinogenic and noncarcinogenic risks associated with potential future exposure to COCs detected in Site 13 subsurface soils. This pathway was evaluated due to a possible future scenario where the subsurface soils are brought to the surface and available for direct contact.

##### *Future Scenario*

##### Ingestion

The total HI for a resident child (0.440) does not exceed unity, suggesting that noncarcinogenic adverse health effects may not occur subsequent to soil ingestion. The calculated ICR, 3.58E-05, falls within the acceptable risk range of  $10^{-4}$  to  $10^{-6}$ .

The total HI for a resident adult (0.0472) does not exceed unity, suggesting that noncarcinogenic adverse health effects are not expected to occur. The calculated ICR of 1.92E-05 falls within the acceptable risk range of  $10^{-4}$  to  $10^{-6}$ .

##### Dermal Contact

The total HI for a resident child (0.303) was below unity, suggesting that noncarcinogenic adverse health effects are not expected to occur subsequent to dermal contact with soil. The calculated ICR, 6.65E-05, falls within the acceptable risk range of  $10^{-4}$  to  $10^{-6}$ .

The total HI for a resident adult (0.207) was also below unity, suggesting that noncarcinogenic adverse health effects are not expected to occur. The calculated ICR of 2.27E-04 falls above the acceptable risk range of  $10^{-4}$  to  $10^{-6}$  due to the presence of pentachlorophenol, and beryllium.

#### 6.9.2.3 Groundwater

**Table 6-23** presents the carcinogenic and noncarcinogenic risks associated with potential future exposure to COCs detected in Site 13 groundwater.

##### Ingestion

##### *Future Scenario*

The total HI for a resident child (0.745) does not exceed unity suggesting that noncarcinogenic adverse health effects may not be expected to occur subsequent to ingestion of groundwater. The ICR for a resident child exposed incidentally to groundwater was 7.27E-05, which is within USEPA's target cancer risk range of  $10^{-4}$  to  $10^{-6}$ .

The total HI for a resident adult (0.639) does not exceed unity. This suggests systemic health effects are not expected to occur subsequent to exposure. The ICR for a resident adult exposed incidentally to



TABLE 6-22

**SUBSURFACE SOIL INGESTION AND DERMAL CONTACT RISKS  
FUTURE SCENARIO**

**SITE 13**

**NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

**Ingestion**

Compound	Resident Child		Resident Adult	
	HI	ICR	HI	ICR
Naphthalene	2.72E-05	--	2.91E-06	--
Pentachlorophenol	8.98E-02	2.77E-05	9.62E-03	1.48E-05
Antimony	1.12E-01	--	1.20E-02	--
Arsenic	1.70E-01	6.58E-06	1.83E-02	3.52E-06
Barium	9.63E-03	--	1.03E-03	--
Beryllium	8.44E-04	1.56E-06	9.04E-05	8.33E-07
Chromium	5.42E-02	--	5.81E-03	--
Lead	--	--	--	--
Manganese	3.64E-03	--	3.90E-04	--
<b>Total</b>	<b>4.40E-01</b>	<b>3.58E-05</b>	<b>4.72E-02</b>	<b>1.92E-05</b>

**Dermal Contact**

Compound	Resident Child		Resident Adult	
	HI	ICR	HI	ICR
Naphthalene	4.94E-05	--	3.38E-05	--
Pentachlorophenol	1.63E-01	5.04E-05	1.12E-01	1.72E-04
Antimony	5.09E-02	--	3.48E-02	--
Arsenic	4.90E-02	1.89E-06	3.35E-02	6.45E-06
Barium	8.76E-04	--	5.98E-04	--
Beryllium	7.68E-03	1.42E-05	5.24E-03	4.83E-05
Chromium	2.47E-02	--	1.68E-02	--
Lead	--	--	--	--
Manganese	6.63E-03	--	4.53E-03	--
<b>Total</b>	<b>3.03E-01</b>	<b>6.65E-05</b>	<b>2.07E-01</b>	<b>2.27E-04</b>

HI - Hazard Index

ICR - Incremental Cancer Risk

TABLE 6-23

**GROUNDWATER INGESTION, DERMAL CONTACT, AND INHALATION RISKS  
FUTURE SCENARIO  
SITE 13  
NAVAL AMPHIBIOUS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

**Ingestion**

Compound	Resident Child*		Resident Adult*	
	HI	ICR	HI	ICR
Vinyl chloride	—	2.45E-05	—	1.05E-04
1,2-Dichloroethene (total)	6.52E-02	—	5.59E-02	—
Trichloroethene	2.43E-01	1.37E-06	2.08E-01	5.89E-06
Tetrachloroethene	3.07E-01	1.37E-05	2.63E-01	5.86E-05
1,1,2,2-Tetrachloroethane	—	2.41E-06	—	1.03E-05
Chlorobenzene	1.41E-02	—	1.21E-02	—
Naphthalene	1.21E-03	—	1.04E-03	—
Pentachlorophenol	9.96E-02	3.07E-05	8.53E-02	1.32E-04
Manganese	1.54E-02	—	1.32E-02	—
<b>Total</b>	<b>7.45E-01</b>	<b>7.27E-05</b>	<b>6.39E-01</b>	<b>3.12E-04</b>

**Dermal Contact**

Compound	Resident Child*		Resident Adult*	
	HI	ICR	HI	ICR
Vinyl chloride	—	3.26E-07	—	2.81E-06
1,2-Dichloroethene (total)	1.19E-03	—	1.61E-03	—
Trichloroethene	1.06E-01	5.75E-07	1.38E-01	3.89E-06
Tetrachloroethene	2.07E-01	9.21E-06	2.80E-01	6.24E-05
1,1,2,2-Tetrachloroethane	—	3.95E-05	—	2.61E-07
Chlorobenzene	2.80E-03	—	3.79E-03	—
Naphthalene	2.43E-04	—	3.30E-04	—
Pentachlorophenol	1.88E-01	5.82E-05	2.55E-01	3.94E-04
Manganese	4.49E-04	—	6.08E-04	—
<b>Total</b>	<b>5.01E-01</b>	<b>6.83E-05</b>	<b>6.79E-01</b>	<b>4.62E-04</b>

**Inhalation**

Compound	Resident Child*		Resident Adult*	
	HI	ICR	HI	ICR
Vinyl chloride	—	1.78E-05	—	3.82E-05
1,2-Dichloroethene (total)	—	—	—	—
Trichloroethene	—	2.27E-06	—	4.86E-06
Tetrachloroethene	—	1.73E-06	—	3.70E-06
1,1,2,2-Tetrachloroethane	—	5.28E-06	—	1.13E-05
Chlorobenzene	1.78E-01	—	7.61E-02	—
Naphthalene	—	—	—	—
Pentachlorophenol	—	—	—	—
<b>Total</b>	<b>1.78E-01</b>	<b>2.71E-05</b>	<b>7.61E-02</b>	<b>5.81E-05</b>

\* Exposed as trespasser/recreational

HI - Hazard Index

ICR - Incremental Cancer Risk

groundwater was 3.12E-04, which falls above USEPA's target cancer risk range of  $10^{-4}$  to  $10^{-6}$  due to the presence of 1,1,2,2 tetrachloroethene, pentachlorophenol and tetrachloroethene.

#### Dermal Contact

##### *Future Scenario*

The total HI for a resident child (0.501) falls below unity suggesting that noncarcinogenic adverse health effects may not be expected to occur subsequent to dermal contact with groundwater. The ICR for a resident child exposed incidentally to groundwater was 6.83E-05, which falls within USEPA's target cancer risk range of  $10^{-4}$  to  $10^{-6}$ .

The total HI for a resident adult (0.679) also falls below unity. This suggests systemic health effects are not expected to occur subsequent to exposure. The ICR for a resident adult exposed incidentally to groundwater was 4.62E-04, which falls above USEPA's target cancer risk range of  $10^{-4}$  to  $10^{-6}$  due to the presence of 1,1,2,2-tetrachloroethane and pentachlorophenol.

#### Inhalation

##### *Future Scenario*

The total HI for a resident child (1.78E-01) falls below unity, suggesting that noncarcinogenic adverse health effects are not expected to occur subsequent to inhalation of groundwater via showering. The ICR for a resident child exposed incidentally to groundwater was 2.71E-05, which falls within USEPA's target cancer risk range of  $10^{-4}$  to  $10^{-6}$ .

The total HI for a resident adult (0.0761) falls below unity, suggesting that noncarcinogenic adverse health effects are not expected to occur subsequent to inhalation of groundwater via showering. The ICR for a resident adult exposed incidentally to groundwater was 5.81E-05, which falls within USEPA's target cancer risk range of  $10^{-4}$  to  $10^{-6}$ .

### **6.10 Lead Model**

The health risk analysis for lead was performed using the Integrated Exposure Uptake Biokinetic (IEUBK) Model. The IEUBK Model is a state-of-the-art method to predict blood lead levels in children. The distribution of lead in the body is initially dependent on the rate of delivery by the bloodstream to various organs and tissues. The most common method of assessing lead exposure is measurement of lead in the blood (USEPA, 1990(b)). The IEUBK Model for lead is designed to model exposure from lead in air, water, soil, dust, paint, and other sources with pharmacokinetics modeling to predict blood lead levels in children aged 6 months to 7 years old. The IEUBK Model was designed for estimating risks from childhood lead exposure to soil and household dust that might be encountered at CERCLA/RCRA sites, but it can be used for other applications, as in the present study. Default parameters are recommended unless there is sufficient data to characterize site-specific conditions.

The IEUBK Model predicts the likely blood lead distribution for children, given the exposure to lead at a given site, and the probability that children exposed to lead in that environment will have blood lead concentrations exceeding a health-based level of concern.

Exposure to lead during infancy and childhood increases the risk of irreversible neurobehavioral deficiencies at levels of internal exposure of 10 to 15 micrograms ( $\mu\text{g}$ ) Pb per 100 milliliters (mL) of blood (10 to 15  $\mu\text{g}/\text{deciliter}$  (dL)). Lead has many known sources, and many pathways from its environmental sources into a child's body (U.S. Environmental Protection Agency, 1986). The Environmental Protection Agency has developed methods for relating environmental lead concentrations to blood lead concentrations in children.

The four main components of the IEUBK Model are:

- An exposure model that relates environmental lead concentrations to age-dependent lead intake into the gastrointestinal tract.
- An absorption model that associates lead intake into the gastrointestinal tract and lead uptake into the blood.
- A biokinetic model that relates lead uptake in the blood to the concentrations of lead in several organs and tissues.
- A model for exposure uncertainties and for population variability in absorption and biokinetics.

As with any multi-compartmental model, pools in the compartmental analysis can be identified with specific organs or organ systems if the biological concentrations in the different compartments are known. For some compartments, the biological concentrations have been measured at a number of time points so that the movement of lead from one compartment to another can be estimated.

While the model has been used in support of the NAAQS for Lead, the Clean Water Act national regulations, and several other regulatory and enforcement issues, USEPA is continuing its validation of the IEUBK Model with a detailed evaluation of additional data collected from different types of sites.

In the evaluation of the model's results, the criteria used are as follow: USEPA's acceptable blood lead concentration level of 10  $\mu\text{g}/\text{dL}$ , and a probability density of 95% or greater of having a blood lead level of 10  $\mu\text{g}/\text{dL}$ . Therefore, if results show a geometric mean blood lead concentration of greater than 10  $\mu\text{g}/\text{dL}$ , a health risk is evident for children ages 0 to 84 months based on the lead concentrations detected in the specific site. If results show a geometric mean blood lead concentration of less than 10  $\mu\text{g}/\text{dL}$ , and the probability of having this blood lead level is 95% or greater, no health risk is evident for children. However, if the results show a geometric mean blood lead concentration of less than 10  $\mu\text{g}/\text{dL}$ , and the probability of having this blood lead level is less than 95%, this RA conservatively assumes a health risk is evident for children ages 0 to 84 months based on the lead concentrations detected in the specific site.

### 6.10.1 Site-12

#### Input Parameters

The average concentration of lead detected in sediment samples was used as the soil concentration input to the IEUBK model since no surface soil samples were collected at Site 12. The average surface water sample concentration was used as the drinking water input. Subsurface soil sample concentrations were found to be lower than the sediment sample concentrations and hence were not used as a soil concentration input. Similarly, groundwater sample concentrations were lower than surface water sample concentrations and hence were not used as drinking water input. Samples with non-detected (ND) values were not included when computing the average lead concentration. The inhalation pathway via dust using outdoor and indoor air lead concentrations were not considered in this RA. The air concentrations used as an input to the IEUBK model for Site 12 are defaults as shown in Appendix K. The lead concentration used as an input for the fish concentration is the average lead concentration detected in the surface water multiplied by the bioconcentration factor for lead which is 49 L/kg. Ingestion rates for drinking water, soil/dust, and dietary lead intake used are the program default values.

#### Results

Figures K-1, K-3, and K-5 in Appendix K show the percent probability of blood lead concentration in  $\mu\text{g/dL}$  for children from 0 to 84 months of age for soil and dust, drinking water, and fish in diet, respectively. While the probable blood lead concentrations is lower than USEPA's level of concern of 10  $\mu\text{g/dL}$  for surface water and sediments (soil), the probable blood lead concentration is above the USEPA's level of concern of 10  $\mu\text{g/dL}$  for the leaded fish diet intake case, with a geometric mean of 13.7 and a 72.73 percent probability of having a blood lead level of 10  $\mu\text{g/dL}$ . Figure K-2, K-4, and K-6 in Appendix K shows the probability density function and the percentage of values below and above the level of concern for the aforementioned cases.

### 6.10.2 Site-13

#### Input Parameters

The average concentration of lead detected in subsurface soil samples was used as the soil concentration input to the IEUBK model since none of the other media samples collected at Site 13 indicated the presence of lead. Samples with non-detected (ND) values were not included when computing the average lead concentration. Ingestion rates for drinking water, soil/dust, and dietary lead intake used are the program default values.

#### Results

Figure K-7 in Appendix K shows the percent probability of blood lead concentration in  $\mu\text{g/dL}$  for children from 0 to 84 months of age for soil and dust. The probable blood lead concentrations is lower than USEPA's level of concern of 10  $\mu\text{g/dL}$  for subsurface soil, with a geometric mean of 1.6 and a zero percent probability of having a blood lead level of 10  $\mu\text{g/dL}$ . Figure K-8 in Appendix K shows the

probability density function and the percentage of values below and above the level of concern for the aforementioned cases.

### **6.11 Combined Risk Levels and Hazard Indices Across Pathways**

**Table 6-24** presents the combined potential carcinogenic risk and hazard index for each receptor considered to have multiple pathways of exposure for present and future use scenarios at NAB Little Creek Sites 12 and 13.

In the current use exposure scenarios for Site 12 the trespasser child, worker adult, and trespasser adult have combined carcinogenic use of  $8.09\text{E-}04$ ,  $1.425\text{E-}04$  and  $6.63\text{E-}06$ , respectively. Site 12 future use scenarios for resident child and adult have combined carcinogenic use of  $1.04\text{E-}03$  and  $2.94\text{E-}03$ , respectively and HI of  $8.94\text{E+}01$  and  $2.53\text{E+}01$ , respectively.

In the current use exposure scenarios for Site 13 the trespasser child, worker adult and the trespasser adult have combined carcinogenic use of  $8.47\text{E-}06$ ,  $2.90\text{E-}04$  and  $4.05\text{E-}05$  and HI of  $1.24\text{E-}03$ ,  $9.80\text{E-}03$  and  $1.15\text{E-}03$ , respectively. Site 13 future use scenarios for resident child and resident adult have combined carcinogenic risk of  $4.83\text{E-}04$  and  $1.59\text{E-}03$  and HI of  $2.20\text{E+}00$  and  $1.67\text{E+}00$ , respectively.

### **6.12 Sources of Uncertainty**

Uncertainties are encountered throughout the process of completing RAs. This section discusses the sources of uncertainty inherent in the following elements of the public health and environmental evaluation performed at these sites:

- Analytical data
- Exposure assessment
- Toxicity assessment
- Risk characterization
- Chemicals not quantitatively evaluated

Uncertainties associated with this RA are discussed in the following paragraphs.

#### **6.12.1 Environmental Sampling and Analysis**

The development of a risk assessment depends on the reliability and also the uncertainties with the analytical data available to the risk assessor. Analytical data are limited by the precision and accuracy of the methods of analysis. In addition, the statistical methods used to compile and analyze the data (mean concentrations, detection frequencies) are subject to the overall uncertainty in data measurement. Furthermore, chemical concentrations in environmental media fluctuate over time and with sampling locations. Analytical data must be sufficient to consider both the temporal and spatial characteristics of contamination at the site with respect to exposure.

TABLE 6-24

**RISK LEVELS AND HAZARD INDEX VALUES  
SUMMARY ACROSS EXPOSURE PATHWAYS  
NAVAL AMPHIBIANS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

<b><u>Site 12-Trespasser Child</u></b>	<b><u>Carcinogen Risk Levels</u></b>	<b><u>Hazard Index Values</u></b>
Surface Water		
Ingestion	2.81E-04	6.83E+01
Dermal Contact	5.27E-04	4.70E+00
Sediments		
Ingestion	5.46E-07	3.54E-02
Dermal Contact	6.22E-07	2.28E-02
<b>TOTAL</b>	<b>8.09E-04</b>	<b>7.31E-01</b>
 <b><u>Site 12 - Worker Adult</u></b>		
Surface Water		
Ingestion	1.79E-04	1.05E+01
Dermal Contact	2.12E-04	2.27E+00
Sediments		
Ingestion	2.18E-06	3.39E-02
Dermal Contact	3.16E-05	2.78E-01
<b>TOTAL</b>	<b>4.25E-04</b>	<b>1.31E+01</b>
 <b><u>Site 12 - Trespasser Adult</u></b>		
Surface Water		
Ingestion	3.01E-04	1.46E+01
Dermal Contact	3.57E-04	3.18E+00
Sediments		
Ingestion	5.85E-07	7.59E-03
Dermal Contact	4.25E-06	3.12E-02
<b>TOTAL</b>	<b>6.63E-04</b>	<b>1.78E+01</b>

TABLE 6-24

**RISK LEVELS AND HAZARD INDEX VALUES  
SUMMARY ACROSS EXPOSURE PATHWAYS  
NAVAL AMPHIBIANS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

**Site 12 - Resident Child**

Groundwater		
Ingestion	3.28E-04	3.37E+00
Dermal Contact	4.35E-05	1.27E+00
Inhalation	2.12E-04	--
Surface Water		
Ingestion	2.81E-04	6.83E+01
Dermal Contact	1.05E-04	4.70E+00
Sediments		
Ingestion	1.36E-05	8.85E-01
Dermal Contact	1.56E-05	5.71E-01
Fish		
Ingestion	6.42E-05	8.33E+00
Subsurface Soil		
Ingestion	6.36E-06	1.11E+00
Dermal Contact	2.44E-06	6.77E-01
<b>TOTAL</b>	<b>1.04E-03</b>	<b>8.92E+01</b>

**Site 12 - Resident Adults**

Groundwater		
Ingestion	1.40E-03	2.89E+00
Dermal Contact	2.94E-04	1.73E+00
Inhalation	4.55E-04	--
Surface Water		
Ingestion	3.01E-04	1.46E+01
Dermal Contact	3.56E-04	3.18E+00
Sediments		
Ingestion	7.31E-06	9.48E-02
Dermal Contact	5.27E-05	3.86E-01
Fish		
Ingestion	6.88E-05	1.78E+00



TABLE 6-24

**RISK LEVELS AND HAZARD INDEX VALUES  
SUMMARY ACROSS EXPOSURE PATHWAYS  
NAVAL AMPHIBIANS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

Subsurface Soil		
Ingestion	3.41E-06	1.18E-01
Dermal Contact	8.31E-06	4.62E-01
TOTAL	2.94E-03	2.53E+01

**Site 13 - Trespasser Child**

Surface Soil		
Ingestion	3.00E-06	4.77E-04
Dermal Contact	5.47E-06	7.66E-04
TOTAL	8.47E-06	1.24E-03

**Site 13 - Worker Adult**

Surface Soil		
Ingestion	1.20E-05	4.57E-04
Dermal Contact	2.78E-04	9.34E-03
TOTAL	2.90E-04	9.80E-03

**Site 13 - Trespasser Adult**

Surface Soil		
Ingestion	3.22E-06	1.02E-04
Dermal Contact	3.73E-05	1.05E-03
TOTAL	4.05E-05	1.15E-03

**Site 13 - Resident Child**

Surface Soil		
Ingestion	7.51E-05	1.19E-02
Dermal Contact	1.37E-04	1.92E-02

**TABLE 6-24**

**RISK LEVELS AND HAZARD INDEX VALUES  
SUMMARY ACROSS EXPOSURE PATHWAYS  
NAVAL AMPHIBIANS BASE - LITTLE CREEK  
VIRGINIA BEACH, VIRGINIA**

Groundwater		
Ingestion	7.27E-05	7.45E-01
Dermal Contact	6.83E-05	5.01E-01
Inhalation	2.71E-05	1.78E-01
Subsurface Soil		
Ingestion	3.58E-05	4.40E-01
Dermal Contact	6.65E-05	3.03E-01
<b>TOTAL</b>	<b>4.83E-04</b>	<b>2.20E+00</b>

**Site 13 - Resident Adult**

Surface Soil		
Ingestion	4.02E-05	1.28E-03
Dermal Contact	4.64E-04	1.31E-02
Groundwater		
Ingestion	3.12E-04	6.39E-01
Dermal Contact	4.65E-04	6.79E-01
Inhalation	5.81E-05	7.61E-02
Subsurface Soil		
Ingestion	1.92E-05	4.72E-02
Dermal Contact	2.27E-04	2.07E-01
<b>TOTAL</b>	<b>1.59E-03</b>	<b>1.67E+00</b>

This risk assessment assumes a log normal distribution of the analytical data which is consistent with USEPA's (OSWER 9285.7-081) view that in most cases, it is reasonable to assure that superfund sampling data are log normally distributed. Dean (1981) also confirms that most environmental data sets are skewed and the data can be assumed to be log normally distributed. In addition use of the assumption that the data are log normally distributed is more conservative because calculating the UCL of the arithmetic mean based on a normal distribution may result in a lower UCL for the same data base (OSWER 9285.7-081), thereby under estimating potential risk. In addition where the site characterization may not have sampled the heavily contaminated portion of the site adequately, in such cases a UCL from a normal distribution could fall below the true mean even if a limited data set appears normally distributed, thereby under estimating the site risk.

### **6.12.2 Exposure Assessment**

In performing exposure assessments, uncertainties arise from two main sources. First, uncertainties arise in estimating the fate of a compound in the environment, including estimating the release and transport in a particular environmental medium. Second, uncertainties arise in estimating chemical intake from contact by a receptor with a particular medium.

To estimate an intake, assumptions must be made about exposure vents, exposure durations, and the corresponding assimilation of constituents by the receptor. Exposure factors have been generated by the scientific community and undergone review by the USEPA. The USEPA published an Exposure Factors Handbook which contains these values. These exposure factors have been derived from a range of values generated by studies of limited numbers of individuals. In all instances, the values used in this RA, scientific judgements, and conservative assumptions agree with those of the USEPA.

The use of a Reasonable Maximum Exposure (RME) approach, designed as not to underestimate daily intakes, was employed throughout this RA. Using the maximum values as the concentration term in estimating the chronic daily intake (CDI) reduces the potential for underestimating exposure at these sites. Additionally, using a contaminant's concentration data in a media, even if present below the screening values, if present in relatively large concentrations or throughout other media at the site, further reduces the potential for underestimating exposure.

Total inorganic analytic results in groundwater were used to represent "at the tap" conditions. This provides a conservative overestimation of potential risks for the identified COCs. However, total dissolved (filtered) inorganic groundwater samples were evaluated to reduce overestimation of risk if the unfiltered sample indicated that the associated risk exceeded an HI value of 1.0 or an ICR greater than  $1.0 \times 10^{-4}$ .

Using total inorganic analytical results in surface water for fish bioaccumulation provides an overestimation of the concentrations which are available for fish bioconcentration.

### **6.12.3 Toxicological Assessment**

In making quantitative estimates of the toxicity of varying dosages of compounds to human receptors, uncertainties arise from two sources. First, data on human exposure and the subsequent effects are

usually insufficient, if available at all. Human exposure data usually lack adequate concentration estimations and suffer from inherent temporal variability. Therefore, animal studies are often used and new uncertainties arise from the process of extrapolating animal results to humans. Second, to obtain observable effects with a manageable number of experimental subjects, high doses of a compound are often used. In this situation, a high dose means that high exposures are used in the experiment with respect to most environmental exposures. Therefore, when applying the results of the animal experiment to the human condition, the effects at the high doses must be extrapolated to approximate effects at lower doses.

For compounds believed to cause threshold effects (i.e., noncarcinogens) safety factors are employed in the extrapolation of effects from animals to humans and from high doses to low doses. In deriving carcinogenic potency factors, the 95th percent upper confidence value is utilized by the agency to prevent an underestimation of potential risk.

Toxicity information for cobalt, iron, dibenzofuran, and 2-methylnaphthalene used in this health risk assessment was provided by USEPA's Environmental Criteria and Assessment Office (ECAO). The use of the provisional chronic oral RfD (reference dose) of 0.3 mg/kg-day for iron, as derived by ECAO, highly overestimates the calculated hazard index (HI) for iron. This RfD supplies adequate levels of iron to meet the nutritional requirement of adults and adolescents over a lifetime, as noted by ECAO. Therefore, the sites in this RA where iron dominates in the exceedance of the HI are overly conservative by using the iron RfD of 0.3 mg/kg-day.

The use of conservative assumptions results in quantitative indices of toxicity that are not expected to underestimate potential toxic effects, but may overestimate effects by an order of magnitude or more.

#### **6.12.4 Risk Characterization**

The risk characterization bridges the gap between risk assessment and risk management, ultimately providing the impetus for the remediation of the site.

Uncertainties associated with risk characterization include the assumption of chemical additivity and the inability to predict synergistic or antagonistic interactions between COCs. These uncertainties are inherent in all inferential risk assessments. USEPA specified inputs to the quantitative risk assessment and toxicological indices are calculated to be protective of the human receptor and to err conservatively, therefore, not underestimating potential human health risks.

### **6.13 Conclusions and Recommendations**

This risk assessment suggests that carcinogenic and noncarcinogenic risks exist at Sites 12 and 13 for a number of media, pathways, and receptors. These risks are summarized below, and are detailed in Section 6.6.

As discussed in Section 6.5, risks are characterized and evaluated by comparing indices to standard values. Cancer risks are expressed in the incremental cancer risk (ICR), and are said to be evident when the ICR is greater than or equal to  $1 \times 10^{-4}$ . Noncancer risks are expressed in the hazard index (HI), and are said to be evident when the (HI) exceeds 1.

### 6.13.1 Site 12

#### Conclusion

Lead concentrations detected in the surface water and sediment in Site 12 pose a health risk for children from 0 to 84 months of age. The IEUBK model results showed there is a high probability that child blood levels would exceed the USEPA's blood level of concern.

#### *Current Scenario*

A number of health risks exist for the surface water ingestion pathway in the current scenario. The trespasser child HI and ICR were exceeded (68.3 and  $2.81 \times 10^{-4}$ , respectively). In the ICR case, arsenic and beryllium were the controlling pollutants. Moreover, inorganics such as arsenic, barium, cadmium, copper, iron, manganese, vanadium, and zinc were the controlling pollutants in the exceedance of HI. The trespasser and worker adult ingestion scenario HIs and ICRs also exceed USEPA benchmarks. The surface water dermal contact exposure for a trespasser child exceeds unity (4.70) and USEPA's acceptable risk range due to several volatile organics and inorganics.

#### *Future Scenario*

A number of health risks may occur in the future scenario. Two groundwater pathways express a degree of risk on this site in the future scenario. Via ingestion, the resident child's and adults HI was exceeded (3.77 and 2.89 respectively). Via dermal contact, the resident child's HI was exceeded (1.27), as was the adult's HI and ICR ( $1.78$  and  $2.94 \times 10^{-4}$  respectively). In each case, vinyl chloride, 1,2-dichloroethene, trichloroethene, and tetrachloroethene were the controlling pollutants. Trichloroethene, vinyl chloride and 1,2-dichloroethene (total) are most likely environmental degradation products of tetrachloroethene. Although TCE may have been used as a dry cleaning fluid the other compounds were most likely not introduced into the environment from another source or as separate pollutants. Inhalation ICRs for children and adults exceed USEPA acceptable levels at  $2.12 \times 10^{-4}$  and  $4.55 \times 10^{-4}$ , respectively primarily due to vinyl chloride.

In addition to the groundwater, the surface water ingestion pathway may pose a risk in the future scenario. The HI and ICR were exceeded for the resident child (68.3 and  $2.81 \times 10^{-4}$ , respectively) and adult (14.6 and  $3.01 \times 10^{-4}$ , respectively). In the ICR case, arsenic and beryllium were the controlling pollutants. Moreover, inorganics such as arsenic, barium, cadmium, copper, iron, manganese, vanadium, and zinc were the controlling pollutants in the exceedance of HI. Dermal contact was also of concern for child HI and ICR exceedences ( $4.70 \times 10^0$  and  $1.05 \times 10^{-4}$  respectively) and for adults 3.18 and  $3.56 \times 10^{-4}$ , respectively.

The Site 12 fish ingestion resident child and adult exposure HI exceeds unity 8.38 and 1.78 respectively due to the presence of arsenic and mercury. The resident child ingestion exposure to subsurface soil exceeds unit (1.11) due primarily to arsenic, iron, vanadium, and chromium.

#### *Recommendation*

Site 12 remedial activities should focus on removing metals, specifically arsenic and lead, and 1,2-dichloroethene, chloroform, trichloroethene, and tetrachloroethene from the surface water and groundwater.

#### **6.13.2 Site 13**

##### Conclusion

##### *Current Scenario*

Health risks are not evident in Site 13 since neither the HI nor the ICR were exceeded for each pathway and receptor. However, the Site 13 subsurface soil ICR in the previous investigation did indicate a potential health risk. The ICR decreased as a result of combining the previous sample results with the supplemental data.

##### *Future Scenario*

The groundwater pathway exhibited a number of risks. The resident adult groundwater ingestion pathway ICR exceeded USEPA's risk range at 3.12E-04. In this case, 1,1,2,2-tetrachloroethene and pentachlorophenol were the controlling pollutants for ICR. Also in groundwater, some indices exceeded their thresholds in the dermal contact pathway. The resident adult exceeded the ICR (4.62E-04). In all cases, pentachlorophenol, trichloroethene, tetrachloroethene, and 1,1,2,2-tetrachloroethane were the controlling pollutants.

##### *Recommendations*

Site 13 remedial activities should focus on removing organics, specifically pentachlorophenol vinyl chloride, trichloroethene and tetrachloroethene, from the surface water and groundwater. Additional investigations may be undertaken to confirm these findings, augment this study, and accurately delineate the location of the risk controlling chemicals for design purposes.

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## 7.0 CONCLUSIONS AND RECOMMENDATIONS

The conclusions have been based on the physical nature of the sites and chemical nature of the sites. Chemical nature of the sites are also quantified by risk analysis.

### 7.1 Site 12 - Exchange Laundry Waste Disposal Area

#### Physical

A total of seven soil borings were drilled at the site, five of which were to install monitoring wells. The top 4 to 6 inches of each boring consists of top soil and organic materials such as grass and root matter. A clay layer approximately four feet thick is found immediately below top soil in both borings LC12-GW1, LC12-GW3, and LC12-GW9. This clay layer is not present in the other borings at the site. The clay layer was found immediately below the top soil at soil borings 12SB-01 and 12SB-02 at a thickness of five to six feet thick. At the five monitoring well locations, a mixed sand/clay layer was found to a depth of four to five feet immediately below the top soil. Below this layer, a layer of fine to medium sand was observed at all monitoring well locations. The sand layer is homogeneous, with traces of silt, thin clay lenses (approximately 6 inches thick or less), and small gravel. This layer ranged in depth from 21 feet bgs in borings LC12-GW5, LC12-GW6, and LC12-GW9 to 24 feet bgs in boring LC12-GW7. Below the sand layer is a very solid grey clay. This clay was encountered at all five monitoring well locations, and is of undetermined thickness.

Groundwater flow is to the south/southwest, towards the drainage canal. Previous investigations have concluded that groundwater flow is to the west, towards the drainage canal. This change in groundwater flow direction may be attributed to construction activities at the site, and/or the availability of additional groundwater level data. The average hydraulic gradient calculated for the site during this investigation is  $1.2 \times 10^{-3}$  ft/ft.

Water in the drainage canal is shallow (less than 1 foot in depth) and appeared stagnant, or very slow moving to the north at all times of observation. This is consistent with observations made during previous investigations at the site.

#### Chemical

Affected media at Site 12 consist of VOC and TAL Metal-contaminated groundwater, and surface water with TAL metals as the constituents of concern. Site 12 groundwater contamination has been found in a number of the monitoring wells at the site, with the highest levels observed in monitoring wells LC12-GW4 and LC12-GW5. TAL metals were detected at levels which exceeded their respective standards at a number of locations. Based on the chemical data generated during this investigation, the VOC plume is located in the area surrounded by monitoring wells LC12-GW1, LC12-GW2, LC12-GW3, and LC12-GW9.

Lead was detected above its standard in the sediment samples collected from the site. These samples were taken downstream from Site 12. Past sampling has provided similar results, though the contamination detected in the sediment samples can not be attributed solely to activities conducted at Site 12.

### Risk Assessment

#### Conclusion

Lead concentrations detected in the surface water and sediment in Site 12 pose a health risk for children from 0 to 84 months of age. The IEUBK model results showed there is a high probability that child blood levels would exceed the USEPA's blood level of concern.

#### *Current Scenario*

A number of health risks exist for the surface water ingestion pathway in the current scenario. The trespasser child HI and ICR were exceeded (68.3 and 2.81E-04, respectively). In the ICR case, arsenic and beryllium were the controlling pollutants. Moreover, inorganics such as arsenic, barium, cadmium, copper, iron, manganese, vanadium, and zinc were the controlling pollutants in the exceedance of HI. The trespasser and worker adult ingestion scenario HIs and ICRs also exceed USEPA benchmarks. The surface water dermal contact exposure for a trespasser child exceeds unity (4.70) and USEPA's acceptable risk range due to several volatile organics and inorganics.

#### *Future Scenario*

A number of health risks may occur in the future scenario. Two groundwater pathways express a degree of risk on this site in the future scenario. Via ingestion, the resident child's and adults HI was exceeded (3.77 and 2.89 respectively). Via dermal contact, the resident child's HI was exceeded (1.27), as was the adult's HI and ICR (1.78 and 2.94E-04 respectively). In each case, vinyl chloride, 1,2-dichloroethene, trichloroethene, and tetrachloroethene were the controlling pollutants. Trichloroethene, vinyl chloride and 1,2-dichloroethene (total) are most likely environmental degradation products of tetrachloroethene. Although TCE may have been used as a dry cleaning fluid the other compounds were most likely not introduced into the environment from another source or as separate pollutants. Inhalation ICRs for children and adults exceed USEPA acceptable levels at 2.12E-04 and 4.55E-04, respectively primarily due to vinyl chloride.

In addition to the groundwater, the surface water ingestion pathway may pose a risk in the future scenario. The HI and ICR were exceeded for the resident child (68.3 and 2.81E-04, respectively) and adult (14.6 and 3.01E-04, respectively). In the ICR case, arsenic and beryllium were the controlling pollutants. Moreover, inorganics such as arsenic, barium, cadmium, copper, iron, manganese, vanadium, and zinc were the controlling pollutants in the exceedance of HI. Dermal contact was also of concern for child HI and ICR exceedences (4.70E+00 and 1.05E-04 respectively) and for adults 3.18 and 3.56E-04, respectively.

The Site 12 fish ingestion resident child and adult exposure HI exceeds unity 8.38 and 1.78 respectively due to the presence of arsenic and mercury. The resident child ingestion exposure to subsurface soil exceeds unit (1.11) due primarily to arsenic, iron, vanadium, and chromium.

### *Recommendation*

Site 12 remedial activities should focus on removing metals, specifically arsenic and lead, and 1,2-dichloroethene, chloroform, trichloroethene, and tetrachloroethene from the surface water and groundwater.

## **7.2 Site 13 - Public Works PCP Dip Tank And Wash Rack**

### Physical

Eight shallow soil borings and five monitoring wells were installed during this investigation. The majority of the site is paved or gravel covered. Below the initial layer of asphalt and/or gravel is a thin, one foot thick layer of sand. This clay layer was observed at the majority of monitoring well locations and ranged in thickness from 2 feet at monitoring well LC13-GW12 to 8 feet at monitoring well LC13-GW8. Sand is then encountered at all boring locations at Site 13. Monitoring well LC13-GW1, installed during a previous study, encountered a second clay layer at a depth of approximately 19 feet bgs.

Groundwater flow is relatively flat, with a slight trend towards the southwest. Previous investigations have similarly concluded that groundwater flow is to the west/southwest. The average hydraulic gradient across the site  $1.46 \times 10^{-3}$  ft/ft. Site 13 is located within approximately a mile of Chesapeake Bay and only slight tidal influence would be expected at this location.

### Chemical

The affected environmental medium for Site 13 is groundwater. In addition, an area investigated during the RI located a localized area of subsurface soil contaminated with PCP around monitoring well LC13-GW8. This area was investigated during the RI. The SRI characterized soils around this boring and found no PCP contamination above RBCs. Soil samples were collected at locations ranging from 20 to 40 feet from LC13-GW8.

VOCs have been detected in the majority of the groundwater samples, with the highest levels being at LC13-GW6. A number of VOCs were detected at levels which exceeded their respective standards at a number of locations. Pentachlorophenol was detected at levels which exceeded its standard. The highest levels of SVOCs have been detected at LC13-GW8. Based on the chemical data generated during this investigation, the VOC plume is located in the area surrounded by monitoring wells LC13-GW3, LC13-GW4, LC13-GW9, LC13-GW12, and LC13-GW13.

## Risk Assessment

### Conclusion

#### *Current Scenario*

Health risks are not evident in Site 13 since neither the HI nor the ICR were exceeded for each pathway and receptor. However, the Site 13 subsurface soil ICR in the previous investigation did indicate a potential health risk. The ICR decreased as a result of combining the previous sample results with the supplemental data.

#### *Future Scenario*

The groundwater pathway exhibited a number of risks. The resident adult groundwater ingestion pathway ICR exceeded USEPA's risk range at  $3.12\text{E-}04$ . In this case, 1,1,2,2-tetrachloroethene and pentachlorophenol were the controlling pollutants for ICR. Also in groundwater, some indices exceeded their thresholds in the dermal contact pathway. The resident adult exceeded the ICR ( $4.62\text{E-}04$ ). In all cases, pentachlorophenol, trichloroethene, tetrachloroethene, and 1,1,2,2-tetrachloroethane were the controlling pollutants.

#### *Recommendations*

Site 13 remedial activities should focus on removing organics, specifically pentachlorophenol vinyl chloride, trichloroethene and tetrachloroethene, from the surface water and groundwater. Additional investigations may be undertaken to confirm these findings, augment this study, and accurately delineate the location of the risk controlling chemicals for design purposes.



### **7.3 RECOMMENDATIONS**

Characterization is sufficient at both Sites 12 and 13 for the purpose of remedy screening, evaluation, and selection. Additional evaluation may be needed prior to remedy design, depending on the selected remedy. A feasibility study should be conducted to develop and evaluate alternatives.